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This document has been prepared in partial fulfillment of CDRL line item A004 of System Development Corporation's Air Force Global Weather Central System Architecture Study contract. Efforts for this report were expended under Task 6, "Conceptual Design and Development Plan", performed under contract F04701-75-C-0114 for SAMSO, under the direction of Col. R. J. Fox, YDA.

The purpose of this study has been to optimize the entire AFGWC data process-

ing system from the vantage point of current and future support requirements, addressing the AFGWC data processing system over the 1977 through 1982 time frame. This study was performed under a unique plan which allows complete traceability between user requirements, Air Force Global Weather Central operational functions, requirements levied upon the data system, a proposed component configuration which meets the data system requirements, and a system specification designed to acquire a system which meets these requirements.

The resultant system described has a number of unique features, including total hardware authentication separation of security levels, load leveling accomplished by assigning main processors in accordance with a dynamic priority queue of tasks, and a system-wide network control capability. Other key features include a central data base processor to fill requests for data from other processors, computer operations centers, the use of array processors for accomplishing difficult numerical problems, and sophisticated forecaster console support. These elements have been designed to provide 99.5% reliability in meeting user requirements.

The proposed system architecture consists of five dual processors each of which is about 3.5 times as powerful as an existing AFGWC processor (a Univac 1108). Each dual processor has an array processor which will be capable of very high performance on vector arithmetic. The array processors are used to assist on the difficult numerical problems, including the Advanced Prediction Model for the global atmosphere, as well as very fine grid cloud models and cloud probability models. Some of the new requirements that will be supported with this system are a one minute response to query interface, reentry support for Minuteman, and limited processing of high resolution (0.3 nautical mile) meteorological satellite data. In addition, cloud cover prediction for tactical weapon systems, ionospheric prediction for radio frequency management, and defense radar interference prediction will be supported by this system.

Volumes of this final System/Subsystem Summary Report are as follows:

- Volume 1 - Executive Summary
- Volume 2 - Requirements Compilation and Analysis (Parts 1, 2, and 3)
- Volume 3 - Classified Requirements Topics (Secret)
- Volume 4 - Systems Analysis and Trade Studies
- Volume 5 - System Description
- Volume 6 - Aerospace Ground Equipment Plan
- Volume 7 - Implementation and Development Plans
- Volume 8 - System Specification

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This volume contains a description of the system/design trade studies used in developing the rationale for design decisions related to proposed data system architectures. It is organized according to major data system components (Architectural Domain) referenced in the Trade Study Report Index. Each trade study includes data dealing with:

a. Applicable requirements and background,
b. Design approaches/characteristics,
c. Analysis, and
d. Summary/conclusions.

Tables presented in the first portion of the document provide reference to the linking of each trade study to both key system requirements and system specifications. Each trade study also references individual system specifications of concern. Appendix A to this volume contains an alphabetical index of specific subjects concerned in the tradeoff analyses.

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RELATIONSHIP OF VOLUME STRUCTURE TO DOMAINS

The trade studies contained in this volume are organized according to an augmented version of the architectural domain structure. Trade studies in Sections 1.0 through 9.0 are thus categorized in pertinent areas of this domain; e.g., Section 1.0 contains topics relating to Data Storage, Section 2.0 contains Data Transfer and Routing topics, etc. The final major subdivision of the archiectural domain, "Facilities," is therefore treated in Section 9.0 of this volume. In addition, Section 10.0 has been included to treat aspects of costing, which is an area that is not a specific division of the architectural domain.

The traceability to the architectural domain is further preserved within each section of this volume by arranging the trade studies according to subdivisions of that domain. For example, in Section 1.0, "Data Storage," all trade studies numbered A11-X are associated with the A11 area of the architectural domain, "Storage Devices." In some cases, no trade studies have been made for specific categories; e.g., the absence of trade studies with the A12 prefix indicate that there are no studies associated with the A12 segment memory of the architectural domain (There are, however, trade studies that relate to processor memories under A31, "Processors.") Wherever trades of a more general nature are treated within a category, these are contained at the initial portion of that segment. For example, trade studies A10-1 through A10-6 are six studies each of which encompasses several subtopics under the Data Storage area.

APPLICABLE DOMAIN VS. PAGE NUMBERS

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- A528 Programmer
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A60 Data Input/Display

- A61 Rapid Response Visual
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A30-7	None
A30-8	None
A30-9	A121-1, A123-1 through 11, A311-2, 4, A312-1 through 39, A264-2
A30-10	None
A30-11	None
A31-1	A311-2, 4, 8, A264-2 through 4

A31-2	A132-1 through 6, A341-3, 7
A31-3	A312-1 through 3, A312-5 through 13
A31-4	A341-7
A31-5	A122-2, 3, A313-1 through 17
A31-6	A343-1, A40-1 through 10, A451-1 through 22
A32-1	A331-1 through 18, A528-1 through 12
A32-2	A528-10
A32-3	A214-1, A251-1, A311-10, A342-1 through 10, A641-1, 2, A71-1, A813-1 through 22, A451-13, A331-7, A451-13, A511-7, A513-1, A52-4
A40-1	A811-12
A40-2	A811-12
A40-3	A451-1 through 22
A40-4	A40-4
A40-5	A414-1, 2, 4, 12, 13
A40-6	A411-1, A422-2, A425-1
A40-7	A40-9, 10, A514-9
A42-1	A43-1, A524-1, A821-18, 19
A43-1	None
A43-2	A444-1, A515-1
A43-3	A515-1
A43-4	None
A44-1	A41-5, 6, 9, 11
A44-2	A41-2
A44-3	A514-1
A44-4	A41-1
A44-5	A113-3
A44-6	A411-1
A45-1	A461-1
A46-1	A472-1
A50-1	A20-6, A313-1 through 17, A50-1, 2, A511-3, A20-5, A513-4, A514-6, A515-4
A51-1	A512-1
A51-2	A52-11

A52-1	A52-2 through 4, A52-7 through 15, A52-17 through 19
A52-2	A528-1, 2
A52-3	A52-8, A111-1
A70-1	A528-1 through 12, A72-7, A921-1
A70-2	A331-1 through 18, A72-7
A71-1	A20-1, 2, A50-4 through 8, A511-2 through 8, A512-5 through, A513-9, A514-1 through 5, A516-1, A52-10 through 18, A525-4 through 7, A526-1, A527-3 through 9, A528-11, 12, A529-3 through 5, A813-1, 6, A813-16 through 23, A71-1 through 6, A72-1 through 8, A73-1
A81-1	A811-1 through 12
A81-2	A813-1
A81-3	A311-8 through 9, A264-3, 4
A81-4	A132-1, A813-2
A81-5	A813-1
A81-6	A813-2
A31-7	A527-5, 8, A831-11
A81-8	A813-11
A82-1	A813-1
A82-2	A821-1
A82-3	A821-14
A82-4	A527-3 through 9
A83-1	A831-1 through 12
A84-1	A813-7
A84-2	A813-7
A85-1	A321-11, A323-2, A324-2
A85-2	A528-1 through 8, A52-5
A86-1	A321-1, A512-6
A93-1	A90-1, A93-1, A932-1, A933-1, A934-1, A911-1, A9112-1, A931-1 through 8

INTRODUCTION

The System/Design Trade Study Report is intended to supplement the System Design Specification and the Subsystem Summary Report. It provides traceability to the requirements (Requirement Domain) by referencing key factors involved in making the tradeoff decisions. As part of the Subsystem Summary Report, it also references directly the Design Specifications resulting from the analyses. However, the referenced specification items must be modified after the specifications are finalized. The section organization is the same (at least at the top level) as the characteristics imposed by the requirements (Characteristic Domain) and the components of which the system is comprised (Architectural Domain). Within sections it agrees with the Architectural Domain which will assist in providing easy reference to the document and finding rationale used for design decisions. Each tradeoff analysis contains a unique number to be referenced in the Design Specifications towards the same end.

Previous versions have been supplemented with an introduction to each section describing briefly the current state of the design; these introductions have been deleted since this document is now part of the Subsystem Summary Report.

Following this introduction is the Architectural Domain and the Trade Study Report Index. An alphabetical index is also provided in Appendix A which allows referencing specific subjects in the tradeoff analyses.

To provide traceability, a section on related key requirements is included in each trade study. In addition, an overall comparison of key requirements versus trade studies is provided. The linkage between trade studies and specifications is provided in a central table in the front of the document. Individual specifications are also referenced in each trade study.

1.0 DATA STORAGE

TRADEOFF TITLE

A10-1 What is the distribution of various types of storage?

REQUIREMENTS/BACKGROUND

Storage can be considered to be broken up into four types: memory (for both conventional and array-type processors), fixed head disks (small capacity, fast access), disks (moderate capacity, moderate access), and mass-storage (large capacity, slow access). The needed amounts of these different types of storage must be determined.

DESIGN APPROACHES/CHARACTERISTICS

(See ANALYSIS)

ANALYSIS

a. Memory (Conventional Processor)

(1) Specifications

(a) Required for Models:

Approximately two (2) million characters/computer will be required for the models. This estimate is based on the combined size of the largest model and the operating system. The following table lists numbers of computers and memory sizes which will meet the requirements of the models:

	computer	# of computers	# char/main mem/comp	# char/ext mem/comp
IBM	370/195	6	2,097,152	–
CDC	CY-76	6	1,280,000	640,000
CDC	STAR	6	2,048,000	–

(b) Required for remaining functions:

We assume 5 1100/40 UNIVAC dual processor computers (this includes 1 for backup) can fill the requirement. These machines will be configured at their maximum memory of 524,288 words main and 1,048,576 words extended memory. Maximum memory for these machines is a very cost-effective investment and will allow for easy switching of major functions.

(2) Summary

For the models, use sufficient main memory to execute the largest model.

For the other requirements, 4 - 1100/40s are needed; these will also handle data base management, network control, and act as hosts for array processors. This workload justifies maximum memory for the systems. A 5th 1100/40 is needed for backup. This represents a total of 57 million characters.

b. Memory (Array Processor)

(1) Specifications

Memory sizing for the array processor is done on the basis of facts and assumptions involving the Advanced Prediction Model (APM).

The APM requires a 2° resolution. (This produces a grid made up of 90 X 180 = 16,200 for 12 layers in the atmosphere. This may be reduced by up to 30% due to crowding of the grid at the pole. Thus we use a factor .7 to account for this effect, as suggested by Smagorinsky.)

Forecasts will be produced for data base storage at 2-hour intervals up to 48 hours. From 48 to 72 hours the storage interval will become 6 hours. The time step to be used in the solution of the equation will be one-half an hour.

It will be necessary to store two wind components, pressure height, and the first derivative of each for two points in time. One other factor is a reduction of the grid size by 30% as suggested by Smagorinsky. Finally, we will assume only one atmospheric level will be operated on at a time.

$$\text{(parameters)} \begin{pmatrix}\text{time}\\ \text{steps}\end{pmatrix} \begin{pmatrix}\text{grid}\\ \text{size}\end{pmatrix} \begin{pmatrix}\text{Smagorinsky}\\ \text{factor}\end{pmatrix} \begin{pmatrix}\text{characters}\\ \text{per word}\end{pmatrix}$$

$$6 \times 2 \times 16200 \times .7 \times 4 = 5.4 \times 10^5 \text{ characters}$$

(Note that in the above calculation each word is being converted to four characters. Since array processors work in words, not characters, this is not a very meaningful conversion. It is done, however, to keep the result consistent with other storage types. The factor of "4" is based on the 32-bit word size used by most array processors.)

(2) Summary

Data vectors require 4.5×10^5 characters of memory storage area. Besides, this storage is also required for I/O buffers and microcode program memory. One million characters (10^6) is therefore reasonable for array processor memory requirements. Since there are five array processors, a total of 5×10^6 characters is required.

c. Fixed Head Disks

The following specifications are listed as a means of comparing the relative merits of competitive storage devices:

(1) Specifications

unit	capacity (char)	access time	transfer rate	control unit cost	device cost
432	1.6M	4.3ms	1.4Mch/S	$100K	$ 50K
1782	12.6M	17.0ms	1.4Mch/S	$100K	$150K
8405	8.4M	8.34ms	622Kch/S	$ 90K	$ 80K

On the basis of the above table the 8405 type of unit is believed to be the most cost effective. Four of this type of storage device will be needed for every processor system. This makes a total of 20 fixed-head disks and a storage capacity of 168 million characters.

The four fixed-head disks are separated into two pairs so that each half of a multiprocessor (uniprocessor) can have its own fixed-head disks. Two fixed-head disks are required per uniprocessor for reliability and for use by the operating system and numerical models.

(2) Summary

Fixed-head disk storage will consist of 168 million characters. This will include an area for the operating system, data base index, and roll in/out. All these factors will be new additions to the present state or will increase from it. The 8405 type storage is picked since it represents the best price/performance factor.

d. Disks

The following specifications are listed as a means of comparing the relative merits of competitive disk storage devices:

(1) Specifications

	8440	8433
rotation delay	12.5ms	8.3
head position time	30ms	30
transfer rate	138,700w/s	179,117
control unit cost	$88,000	$92,000
device cost	$30,000	$25,000
capacity	120Mchar	200Mchar

On the basis of the above data the type of unit represented by the 8433 disk is believed to be the superior device and is recommended for use where possible.

The following table itemizes storage requirements of GWC functions on disk type storage. The 8433-type disk has been used whenever possible because it represents the least cost per bit. For raw satellite data, the UNIVAC 8440 has been shown because GWC is building a direct interface to this disk for satellite ingestion and because the 8433-type disk has too much data under one set of heads for good performance in mapping and gridding of raw satellite data. For disks that are used as communications interfaces, the IBM 3340-type disks have been shown because their combination of fixed and movable heads alleviates access conflicts; these have been disked as "H/T - M/H" for head per track - movable head. They have a capacity of approximately 70M characters/pack with an additional .5M characters under fixed heads.

Table 1. Disk Type Storage Requirements

STORAGE DESCRIPTION		STORAGE NEEDED (char)	DEVICE	PACKS NEEDED FOR DATA STORAGE	PACKS FOR RELIABILITY
Meteoroligical Data Base		1020 M	(8433-type)	5.1	5.1
Gridded satellite	DMSP	96 M	(8433-type)	5.5	1
	TIROS	96 M			
	GOES	372 M			
	fine	540 M			
		1104 M			
Raw satellite	DMSP	285 M	(8440-type)	10.3	2
	TIROS	285 M			
	GOES	306 M			
	fine	360 M			
		1236 M			
Software/development		240 M	(8433-type)	1.2	0
Unclassified comm		60 M	(H/T+M/H)	11.1	2
job params		30 M			
consoles		120 M			
scratch		330 M			
prog. abs		120 M			
tape spooling		120 M			
		780 M			
Confidential comm		30 M	(H/T+M/H)	3.4	1 pack
job params		30 M			
scratch		120 M			
Tape spooling		60 M			
		240 M			
Secret comm		30 M	(H/T+M/H)	5.1	1 pack
job params		30 M			
overlay d b		120 M			
scratch		120 M			
tape spooling		60 M			
		360 M			
Top Secret comm		60 M words	(H/T+M/H)	6.1	1 pack
job params		30 M			
scratch		180 M			
tape handling		90 M			
		360 M			

Table 1. Disk Type Storage Requirements (cont'd)

STORAGE DESCRIPTION	STORAGE NEEDED (char)	DEVICE	PACKS NEEDED FOR DATA STORAGE	PACKS FOR RELIABILITY
TSSIOP		(H/T+M/H)	4.7	1 pack
Job params	30 M			
overlay d b	120 M			
scratch	120 M			
tape spooling	60 M			
	330 M			
SA 1 comm	60 M	(H/T+M/H)	9.8	2 packs
job params	30 M			
scratch	240 M			
consoles	120 M			
overlay d b	120 M			
net control	120 M			
	690 M			
SA 2 comm	60 M	(H/T+M/H)	4.7	1 pack
job params	30 M			
scratch	120 M			
tape spooling	120 M			
	350 M			
SA 3 comm	60 M	(H/T+M/H)	4.7	1 pack
job params	30 M			
scratch	120 M			
tape spooling	120 M			
	350 M			

(2) Summary

The 8433 type of disk is preferred since it represents the latest technology and has the best price/performance rating. A combination of disk devices including this type will be needed. A total of 5.7×10^9 characters disk storage are required for basic needs. In order to meet reliability requirements an additional 2.09×10^9 characters will be required.

e. Mass Storage Facility

(1) Specifications

The mass storage facility (MSF) is seen as a replacement for the present magnetic tape storage (see A11-6). The sizing of the storage required must therefore be based on magnetic tape usage for unclassified storage.

Normal access digital computer tapes needed for 1982:

programmer save	5,000
Scratch (6 day save)	600
Misc. Save	1,400
Write Protect	1,112
Satellite Save Scratch	200
	8,312

Assuming a 10% utilization, this is equivalent to 831.2 full tapes.

Full tape capacity:

$$\frac{16{,}536 \text{ characters/block}}{1{,}600 \text{ characters/inch}} + .5 \text{ inch IBG} = 10.8 \text{ inches/block}$$

$$\text{Single tape capacity} = \frac{2.82 \times 10^4 \text{ inches}}{10.8 \text{ inches/block}} \times 16{,}536 \text{ ch/blk} = 4.3 \times 10^7 \text{ ch/tape}$$

$$\text{Total storage needed} = 4.3 \times 10^7 \text{ ch/tape} \times 831.2 \text{ tapes} = 35.7 \times 10^9 \text{ character}$$

Assume 70% of data is amenable to the unclassified MSF,

$$.7 \times 35.7 \times 10^9 \cong 25 \times 10^9 \text{ characters}$$

So total requirement $\sim 25 \times 10^9 + 8 \times 10^9$ ETAC $+ 2 \times 10^9$ (5*% contingency)

$$\cong 35 \times 10^9 \text{ characters}$$

of which 5×10^9 must be with protected

The cost of a mass storage facility providing 35 billion characters of storage is about $.6 million.

(2) Summary

This inexpensive storage eliminates manual handling of tapes, and maximizes efficient utilization of disks by paging data sets to/from disk on demand.

SUMMARY/CONCLUSION

The following represent the requirements for the different types of storage in characters:

Memory (conventional)	$12X10^6$ models
	$45X10^6$ general purpose
Memory (array)	$5X10^6$
Fixed head disks	$168X10^6$
Disks	$7790X10^6$
Mass Storage	$35,000X10^6$

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

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*Not as high for MSF as for 10½ inch reel tapes since more efficient.

RELATED SPECIFICATIONS

A111-1 through A111-9, A112-1 through A112-9, A113-1 through A113-5, A114-1, A115-1 through A115-3, A117-1 through A117-22, A121-1 through A121-3, A122-1 through A122-3, A123-1, A123-6 through A123-11, A231-1, A232-1, A233-1, A234-1, A235-1, A264-3, 4, A312-16, 18, A312-20, 21, 23, 24, 28, 32, 34, G30-11 through 18

TRADEOFF TITLE

A10-2 What is the trade between rapid data transfer versus staging (especially as applied to tape)?

REQUIREMENTS/BACKGROUND

A computer system and its data base can basically rely on two alternatives for communication: first a direct interface which relies on the data transfer rates of the storage device; and second, staging which relocates data from a slower to a faster storage device to save access time when the data are needed at a later point.

DESIGN APPROACHES/CHARACTERISTICS

These basic approaches have been considered in attacking the problem:

a. A direct interface between CPU and the storage devices,

b. Staging of all data base information from a slower storage device to one with a faster access time, and

c. A combination of direct interface and staging designed to minimize the demand on system resources, make maximum use of faster access times of some storage devices, and meet all time requirements.

ANALYSIS

The concepts of direct mass storage interface and staging were discussed in an Ampex Terabit memory article presented at SHARE by Erik Salbu on 6 March 1974. In this article the point is made that the spectrum of mass-storage system interface approaches can be divided into three separate classes: specialized, shared storage devices, and device emulation.

"Most of the early attempts at mass storage systems relied on a special purpose interface directly between the host CPU and the MSS. This is the easiest to build from a hardware standpoint, but requires the host CPU operating system to be changed to treat the MSS as a special device and/or the user programs to be modified to properly access the MSS data.

The emulation interface also involves a direct connection between the host CPU and the MSS. However, in these approaches the MSS is given the sophistication of being able to emulate a standard device (tape or disk). This tape emulation approach is primarily applicable to those applications involving a relatively small number of large sequential files since random access is not easily supported. The most general and desirable approach is probably a disk emulation interface in which the MSS acts as some number of disk controllers with a trillion bits of data on virtual disk devices. Unfortunately, the MSS architecture and access time characteristics to indicate a continuation preclude this type of interface for general purpose installations.

A reasonable compromise in the spectrum of interface approaches is the concept of a shared standard device. In this approach, the MSS acts as a data staging controller transferring large bursts of data (data sets) to a tape or disk drive which is shared between the host CPU and the MSS. This interface has the same advantage as the emulation interface, i.e., the host CPU system and user software require no modifications to process the data."

SUMMARY/CONCLUSION

GWC's needs can be best met by a combination of direct interface and staging designed to minimize the demand on system resources, make maximum use of faster access times of some storage devices, and meet all time requirements.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A117-1 through A117-22, A451-13, G20-11 through 18

TRADEOFF TITLE

A10-3 Are there applications for such things as cassettes, tape reels, diskette and floppy disk?

REQUIREMENTS/BACKGROUND

(See ANALYSIS)

DESIGN APPROACHES/CHARACTERISTICS

(See ANALYSIS)

ANALYSIS

These devices are normally used in keyed data entry and generally have no role at GWC. The exception is in the data declassification manual interface where a floppy disk shall hold the data prior to display to the security monitor and communications positions.

SUMMARY/CONCLUSION

The security downgrade system will consist of a low capacity storage device and a completely independent (no electronic connection) read unit which allows a) display on a CRT to a security monitor; b) switchable manual routing to any classified level disk.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

409 - Environmental Support - Operational Security
416 - Environmental Support - Backup to Carswell

RELATED SPECIFICATIONS

A118-1 through A118-6, A513-4 through A513-8

TRADEOFF TITLE

A10-4 What is the backup/recovery approach for each data type?

REQUIREMENTS/BACKGROUND

For purposes of backup the data base can be considered to be broken up into five types:

a. Meteorological data (gridded and observational);

b. Overlay data bases;

c. Satellite data files;

d. Operating system, comm libraries, program files, and other nontime critical data; and

e. Archival data.

There is presently a requirement and a procedure for backup of all these data types with the exception of satellite and archival data. A decision must be made on what will be considered adequate backup in the future.

DESIGN APPROACHES/CHARACTERISTICS

The following list contains the primary alternatives considered:

a. Have no backup of data files and instead reinitialize the data base.

b. Continue with the present mode of backing up all essential files on magnetic tape only.

c. Purchase enough redundant disk and drum storage so that some essential data base files can be backed up by these faster devices when necessary.

d. Create a backup data base identical in all ways to the primary one and place it on mass storage devices identical to the primary data base.

These different options involve different hardware costs and are closely linked to the configuration of the primary data base. Backup requirements must be balanced against these costs.

ANALYSIS

The present mode of data base backup by magnetic tape is too slow and limited in its access capabilities to efficiently back up the larger mass storage devices (such as the UNIVAC 8433 disk which will be in use before 1982). Magnetic tape will not continue to be an adequate backup for the entire data base. More specifically, because of its large size and the time required to transfer it (both to and from tape), the gridded and observational data base will need to be backed up by disks identical to the primary storage devices. The same arguments hold for the overlay data bases.

Since there is no requirement for backup of the satellite files, the recording of the raw data in the satellite data receiving area (AP) is sufficient for projected needs.

Some files which do not change with short periods of time (like the operating system, comm libraries, and program files) can be continued to be backed up by magnetic tape since the files do not need to be reconstructed as often as other data base files (one tape could serve as a backup).

Finally we consider archival data. Since these data only were constructed for quality control, backup, and transmittal to other facilities, there is no need for recovery procedures; no backup is needed.

SUMMARY/CONCLUSION

Enough redundant disk and drum storage will be purchased so that some essential data base files can be backed up by these faster devices when necessary.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A113-3, A114-1, A115-2, A115-3, A116-1, A116-6, A117-5, A241-9

TRADEOFF TITLE

A10-5 Are satellite data base and meteorological data base different enough to warrant different memory types or is the extra flexibility desired?

REQUIREMENTS/BACKGROUND

The function and origin of the satellite and meteorological data bases are sufficiently different so that they may each warrant unique structures or memory devices.

DESIGN APPROACHES/CHARACTERISTICS

(see ANALYSIS)

ANALYSIS

The types of memory (storage) devices being considered for data base storage have only included:

a. Fixed-Head Disks (low capacity, high speed)
b. Disks (moderate capacity and speed)
c. Mass Storage (high capacity, low speed)

In effect, we are sufficiently limited in our choices so that there cannot be much variation between devices used for meteorological or satellite data bases. (Variation of data base structure is an issue which has already been declared an option for further consideration. See A15-9.)

SUMMARY/CONCLUSION

Since the satellite data base is an integral part of the central data base, the design of the central data base has already determined the type of primary and backup storage to be used for satellite data.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

113 - Special Activities - Program D
120 - Special Activities - ZOOM Use
406 - Environmental Support - Satellite Imagery Dissemination
408 - Environmental Support - Interactive Processing and Display System
602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A444-1, A114-1, A515-1 through A515-4

TRADEOFF TITLE

A10-6 What is the possibility for techniques to establish satellite data compression/rejection criteria with interactive meteorological verification?

REQUIREMENTS/BACKGROUND

The fully automated, reliably consistent, and accurate extraction of useful meteorological phenomena and features observed in presentation of remotely sensed data is currently beyond the state-of-the-art. Criteria for automation have not been established. In the current time frame, the remotely sensed data are presented to the meteorologist in a pictorial format, either on a CRT or more commonly on photographic/facsimile hardcopy. The existence, recognition, and identification of meteorological characteristics containing useful information are manually performed by a perusal process This process is performed manually for both static and dynamic (i.e., time dependent) characteristics. In the latter, time-lapsed sequences are prepared for perusal by a meteorologist in either motion picture film formats (becoming rapidly obsolete) or by refreshing a CRT. The determination of wind vectors from cloud motions derived from selected cloud locations in successive GOES data frames is a current technique exemplifying the use of time-lapsed sequences to extract information from dynamic meteorological phenomena.

DESIGN APPROACHES/CHARACTERISTICS

There are two basic approaches which will satisfy this problem:

a. Manual extraction of meteorological phenomena from hardcopy displays,

b. Automated evaluation of meteorological phenomena for hardcopy or CRT presentation.

ANALYSIS

The attainment of capabilities for fully automated extraction of useful meteorological information from remotely sensed data would be a desirable achievement.

An ability to automatically extract pertinent meteorological information would subsequently enable the following cost conserving advantages to accrue:

a. Reduction in the number and talent level of required meteorological operational personnel (including their training cycle).

b. Minimization of computational growth requirements resulting from elimination of data that do not contain useful meteorological information (this activity is closely related to efforts concerned with development of data rejection algorithms applied during the initial data-stream processing. The problems of data compression are different from those of data rejection).

c. Reduction of time intervals between data input and resulting output of significant meteorological information to enable faster turnaround where meteorological information is perishable (to either the end user as a product, or as initial condition input values for exercising numerical analysis or forecast models).

To achieve automated information extraction it is necessary to establish quantitative criteria and to then invoke numerical pattern recognition and/or signature analysis principles, probably employing both structured and non-structured techniques. A meteorological (numerical) filter(s) would have to be developed for the various types of information to be extracted from the remotely sensed data. This activity can be significantly enhanced by providing a semi-automated (i.e., interactive) capability for the learning process. Once the filter has been established and tested, it can be applied to the operational data stream to automatically extract the meteorological information for which it was designed.

SUMMARY/CONCLUSION

The heuristic capability may be required to achieve automated meteorological information extraction capabilities and the associated long-term operational cost-reduction advantages.

A feasibility analysis and methodical development of techniques and capabilities is required. The goal in the architectural design is to accommodate such investigations and to provide a support structure for possible eventual incorporation of resulting capabilities. The results of the study will not, however, include any specific recommendations because of the lack of time to accomplish any of the required data.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

120 - Special Activities - ZOOM Use

602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A132-14

TRADEOFF TITLE

A11-1 Is multiple simultaneous data base update from several processors warranted?

REQUIREMENTS/BACKGROUND

With similar functions active at the same time on several processors there is an increasing probability that multiple data base updates will be performed simultaneously. Since this adds significant complication to the system, its necessity should be evaluated.

DESIGN APPROACHES/CHARACTERISTICS

(See ANALYSIS)

ANALYSIS

Simultaneous, multiple data base updates from several processors are definitely warranted. It must be this way to accommodate the network control concept of distributing functions among processors to obtain optimum system efficiency. It is also necessary due to the time-line requirements of computing functions.

SUMMARY/CONCLUSION

Allow as many data base updates to occur simultaneously as is necessary to satisfy all function needs.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A131-1, A132-1, A132-4 through A132-12, A341-2

TRADEOFF TITLE

A11-2 How will control be accomplished against simultaneous update and read?

REQUIREMENTS/BACKGROUND

With the concept of a centralized data base, control must be accomplished against simultaneous update and read. If this is not done, the "reader" could end up with a mixed collection of both new and old data.

DESIGN APPROACHES/CHARACTERISTICS

The following approaches to this problem have been considered:

a. Hardware and Executive restraints controlling simultaneous update and reads.

b. Data base update and read being controlled by a central data base manager.

ANALYSIS

If disks are accessed directly by multiple processors, then disk control unit hardware queues requests for accesses to the same physical volume. The problem remains of how to avoid thrashing the disk due to head motion and how to avoid discontinuity due to update while processing. The only answer is to reserve data sets and have a convention for checking the data set status. Executive functions will handle the problem at this level. If reserve becomes necessary below this level, blocks can be reserved on a shared/exclusive basis. Most new access methods have this capability. With a central data base manager, the CPU acting as data base manager will queue requests and reserve resources. Since the design of the data base now calls for such a manager based on other decisions, this step also seems logical.

SUMMARY/CONCLUSION

The ideal solution appears to be a combination of both design approaches, with data base update and read being controlled by a central data base manager through hardware, executive, and protocol constraints.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A341-2

TRADEOFF TITLE

A11-3 What is the output spool buffer required versus the number of devices (e.g., printers)?

REQUIREMENTS/BACKGROUND

Given a variable amount of output to the printer with time it must be decided whether it is more cost effective to buy more printers to handle the job or more disks to buffer to the printer.

DESIGN APPROACHES/CHARACTERISTICS

The two primary alternatives to this problem include procuring more printers to handle the peak load or purchasing more disk storage for more buffer area for output to printer. A cost study must be performed considering these two factors.

ANALYSIS

It is unlikely that problem programs can drive printers at efficient speeds due to wait times for data access and computer between lines. Also, it is doubtful that, in the GWC environment, a single CPU would have enough printout to keep a high-speed printer constantly busy. Since a 2000-line-per-minute (LPM) printer is not twice as expensive as a 1000 LPM printer, it makes sense to centralize and to buffer printing. Operator efficiency and security also suggest that this is a good idea.

What we need to know is the size of disk buffer that is required to handle transients, maintenance down-time, and forms changing time. If we assume that reliability dictates duplicate printers, then we are left with transients. We can probably assume that a priority system allows for time constraints on products, but that a backlog of ordinary printout can build up. Printers come in fixed speeds, so we can assume that GWC will buy enough to handle its problem and simply calculate buffer size as a function of turnaround, given a printer speed.

CASE 1. Given an IBM 3800 equivalent. Assume 90% efficiency in fitting forms to 77" drum. Line rate is then $0.9 * 31.8 \frac{\text{inches}}{\text{sec}} * 100 \frac{\text{char}}{\text{line}} = 17{,}000 \frac{\text{char}}{\text{sec}}$

Backlog (hr)	Buffer Size (char)	200×10^6 Char Packs
3	1.8×10^8	0.9
6	3.7×10^8	1.9
9	5.5×10^8	2.8
12	7.3×10^8	3.7
24	14.7×10^8	7.4

These figures have to be adjusted for the fact that the printer will be unloading the buffer while it is being filled. The maximum transfer rate to disk is 8×10^5 ch/sec. At a minimum, it would take 225 seconds to load a 3-hour backlog, allowing the printer to output 3.8×10^6 characters. This is really an insignificant result in view of the total and in view of the discrete size of storage in 100×10^6 or 200×10^6 character packs.

Case 2. IBM 3211 equivalent. Assume 90% efficiency. Throughput = $0.9 * 2000$ LPM $* 100$ ch/line $* \frac{1 \text{ min}}{60 \text{ sec}} = 3000 \frac{\text{ch}}{\text{sec}}$

Backlog (hr)	Buffer Size (char)	(packs @ 200×10^6 ch/pack)
3	3.2×10^7	0.2
6	6.5×10^7	0.3
9	9.7×10^7	0.5
12	1.3×10^8	0.7
24	2.6×10^8	1.3

Cost Analysis

1	11,000 LPM Printer	250,000
1	2,000 LPM Printer	100,000

based on: UNIVAC 770 2000 LPM $73,455 CDC 580-20 2000 LPM $102,060

1 - 200 X 10^6 character disk (given controller) = \$40,000

1 * 11,000 LPM printer ≅ 6 packs ≅ 19.5 hour backlog for this device.

1 * 2,000 LPM printer ≅ 2.5 packs > 24 hour backlog for this device.

In other words, given that you can handle 24 hours of printing on the device in the steady state, it is cheaper to buy disks for buffers than buy another printer to cut the disk load.

The only reason to buy more printers is for priority work or additional throughput, not to decrease disk buffer size.

The number of disks is not affected by security constraints because one spooled buffer will be used to drive several printers according to the security classification at the output.

Three types of printers are suggested for use at GWC to meet requirements. Their basic difference is the speed at which they operate: 1,000 LPM, 2,000 LPM, and 11,000 LPM. The following tables list the locations and requirements these printers will fulfill:

Printer Speed	Normal Access Perimeter		Special Access Perimeter		Variable Access Perimeter	
	No.	Requirement	No.	Requirement	No.	Requirement
1,000 LPM	4	Maintenance and backup	1	Maintenance and backup	1	Maintenance and backup
2,000 LPM	5	Routine output for four security levels and backup			1	Routine output
11,000 LPM*	2	Product Preparation		-		-

*Chosen for mechanism which permits special character and contours rather than for the high print speed. This prototypical model was selected because, as the most expensive selection in its class, it results in a conservative cost for implementing this architectural feature.

SUMMARY/CONCLUSION

The amount of buffer required to support spooled output should be consistent with the minimum numbers of printers required to support peak average output.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A111-2, A111-4

TRADEOFF TITLE

A11-4 Should the variable perimeter contain storage devices that are not rapidly cleanable, or should this processor system share peripherals with the normal-access or the special-access areas?

REQUIREMENTS/BACKGROUND

The processor system in the variable-access perimeter is intended as a backup system for both the special-access and normal-access perimeters.

DESIGN APPROACHES/CHARACTERISTICS

The tradeoff in this case is between the difficulty of cabling the variable access perimeters to two external peripheral sets versus having peripherals inside the variable access perimeter. Because disks are not rapidly cleanable, they could delay switching of the variable-access perimeter from the special access mode back to a normal-access mode.

ANALYSIS

Because the variable-access perimeter processor system acts as a backup, when it is used it will normally be assuming the role of a failed processor or of a processor which will be taken for preventative maintenance. Hence, all of the data base information it needs to do its work will be contained on disks located either inside the special-access or inside the normal-access perimeters. The variable-access perimeter processor will not need disks or tapes in its own area. Placing disks or tapes in its own area could result in a higher probability of security violation due to the fact that such disk packs or tapes would have to be removed to make a transition from running special access to running in normal-access mode.

SUMMARY/CONCLUSION

The variable access perimeter shall contain only rapidly cleanable devices, e.g., the array processors, main memory, and fixed-head disks.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

100 - Special Activities - All requirements.

RELATED SPECIFICATIONS

A312-23, A263-1, A261-1 (c)

TRADEOFF TITLE

All-5 What buffering should be provided in communications links?

REQUIREMENTS/BACKGROUND

Communications links into AFGWC will be handled by front end devices called line handler/decoder routers (LHDR). The LHDRs will have to have sufficient buffering to ensure that they can handle peak load transients and that they can store-and-forward messages. In addition, buffering should be provided between the communications links and the remainder of the data system to allow processors within the data system time to be upgraded for security reasons or to respond in a prioritized order to messages. It should be noted that the LHDRs are not actually part of AFGWC, but rather belong to the communications squadron. Hence, the concern of this tradeoff study is not so much with the design of the LHDR and its associate peripherals, as it is with the interface to the Global Weather Central. The tradeoff analysis concerns itself with the internal structure of the system of LHDRs only as it pertains to and effects that interface.

DESIGN APPROACHES/CHARACTERISTICS

If the LHDRs were interfaced on a computer-to-computer basis with the remainder of the AFGWC data system, they would require their own disks for buffering. However, this direct computer-to-computer interface is not desirable in the enhanced architecture because of the following reasons:

a. Processors within the data system may not necessarily be at a security level compatible with an LHDR, hence, buffering is required in between the LHDR and the data system.

b. Network Control must manage the scheduling of functions within the data system to meet deadlines and priorities. Therefore, lower priority messages may back up between the LHDRs and the remainder of the data system.

c. Processor-to-processor cabling is more constrained (i.e., must have shorter cables) than processor-to-disk-to-processor communications.

d. The disks on the LHDRs would be an additional expense.

e. Switching of CPU-to-CPU channel speed communication is dangerous in that it has the potential of causing errors that would bring both CPUs down.

ANALYSIS

The LHDRs should be interfaced to disk subsystems of the AFGWC-enhanced architecture rather than directly to processors. The only difficulty in doing this is to overcome the potential bottlenecks of having processors within the AFGWC data system accessing messages placed on disks by LHDRs attached to communications lines. This potential bottleneck can be overcome by using the multiple disk packs for the data sets and providing alternate paths to the disk packs through control units and switches. Also, the nature of the disk packs themselves can be optimized for rapid retrieval of data, i.e., they can be a mixture of fixed and movable head disks such as the IBM 3340. For the IBM 3340, the first five cylinders or so are accessed via fixed heads while the remainder are accessed via movable heads. This arrangement is also convenient for store-and-forward messages which will be accessed solely by the LHDRs. The volume of storage supplied by five cyclinders of the 3340 is approximately .5 million characters per pack, which is more than enough storage for the store-and-forward messages handled by LHDRs.

SUMMARY/CONCLUSION

The only buffering provided in communications links in the enhanced architecture will be that of system disks. The nature of the system disks should be such as to prevent a bottleneck in the accessing of messages within the data system and the pacing of messages on the disks by the LHDRs. To prevent such bottlenecks, multiple disk packs should be used to spread data sets over as many access arms as possible, and multiple control units with multiple ports should be used on a string of disk packs. Furthermore, the disks themselves should be of a nature that have both fixed and movable head areas on them.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A40-1, A451-13, A113-1, through 3

TRADEOFF TITLE

A11-6 Should a manual or automatic mass storage system be selected?

REQUIREMENTS/BACKGROUND

Some automatic storage devices do not require the personnel associated with their manual counterparts. The result then is a savings in manpower and a possible cost savings overall. The savings in personnel is especially attractive at GWC which will undergo no manning increase while requirements for new products continue to rise.

DESIGN APPROACHES/CHARACTERISTICS

There are two possible areas of application for this concept at GWC:

a. All storage internal to GWC which is now done on magnetic tapes can instead use a mass-storage facility;

b. Storage which must continue to use the magnetic tape medium, such as that which will be sent to a customer external to GWC, is a candidate for an automated tape library.

ANALYSIS

The replacement of conventional tape devices for unclassified applications would replace two tape hangers/shift or a total of 10 individuals. The burdened rate for these is about $25,000/year for a total gross savings of $250,000/year.

The IBM 3850-B1 mass storage facility rents for $16,333/month, leading to an annual cost of $195,996.

The Calcomp tape library is much less expensive. Its monthly rental on a 1-year lease (GSA) for a redundant system of 2 LCUs, 4 LSUs is $78,480. An additional one-time cost involves the software interface between the Calcomp machine and UNIVAC hardware. The Census Bureau is currently developing such software for their own use but it will not be supported by Calcomp. SDC estimates that Calcomp could provide fully supported software at a one-time cost of about $100,000.

Total replacement of the personnel involved in tape hanging would require the acquisition of both a mass-storage facility and an automatic tape library at a cost which approximately equals the savings.

SUMMARY/CONCLUSION

There is a definite application for an automatic mass storage system at GWC.

RELATED REQUIREMENTS

This Trade Study is related to the fcllowing requirements:

602 - General - Manpower Productivity

409 - Environmental Support - Operational Security

RELATED SPECIFICATIONS

A117-1 through A117-22, G30-11 through 18

TRADEOFF TITLE

A11-7 Should we consider the 10^9 bit associative memory (such as that being developed for Rome Air Development Center) for the GWC System?

REQUIREMENTS/BACKGROUND

Rome Air Development Center is funding development of a 10^9-bit associative memory to augment their STARAN for data base applications.

DESIGN APPROACHES/CHARACTERISTICS

(See ANALYSIS)

ANALYSIS

In our time-frame the technology would serve to enhance the capabilities of an associative processor. We cannot count on it being available, however.

SUMMARY/CONCLUSION

GWC should monitor the progress of this technology through Rome Air Development Center.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

218 - Command Control Systems - Computer Flight Plans
305 - Emergency War Order Support - SAC
408 - Environmental Support - Interactive Processing and Display System
511 - Space Environment Support - OTHB Radar

RELATED SPECIFICATIONS

There are no specification items pertinent to this conclusion.

RELATED SPECIFICATIONS

None

TRADEOFF TITLE

A11-8 Can a different (e.g., cheaper) medium be utilized for backup?

REQUIREMENTS/BACKGROUND

Because of the size and complexity of GWC's data-base backing, it up can be an expensive problem. A different approach is to use a cheaper medium for backup.

DESIGN APPROACHES/CHARACTERISTICS

Provided that cheaper mediums of storage can meet speed requirements, two of the prime candidate devices are magnetic tape or a mass-storage facility (10^{12}-bit capacity).

ANALYSIS

A typical mass-storage facility holds approximately 35.3×10^9 characters, or about 170 disks worth of data. If it could be used as a backup (e. g., meets access-time criteria) it could quickly pay for itself.

An example is the satellite data base which will require a total backup of about 200×10^6 words by 1982, or 1.2×10^9 characters. The cost of disks to store these data is about 2/3 the price of a mass storage facility. But, in addition to this backup, the mass-storage facility could also be used to store raw satellite files, saving additional disk space and, therefore, more memory.

SUMMARY/CONCLUSIONS

The mass-storage facility may be a feasible alternative medium for backup but should still be carried as an option.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

601 - General Growth

RELATED SPECIFICATIONS

A116-1, A116-6, A117-1, A117-15, A241-9

TRADEOFF TITLE

A13-1 Is there an advantage to a single universal data base with classified overlays instead of a data base for each system?

REQUIREMENTS/BACKGROUND

The data base is primarily made up of observational, gridded meteorological, and satellite-sensed parameters. It is the storage location of the primary input and output fields used by the GWC analysis and forecasting functions. The basic structure of this data base therefore has a definite impact on the computer resources required by these key GWC functions and should be designed accordingly.

DESIGN APPROACHES/CHARACTERISTICS

Because of the nature of the meteorological data base (i.e., size, structure complexity, and requirement for random access), disks are the best storage alternative. The capability will be present (because of the existence of the one-way data line) to upgrade data from the unclassified data base to any higher level.

The present data base design allows for essentially duplicate data bases on each of the component computer systems which comprise GWC. An alternative approach is to have less redundancy and more centralization in the data base design. This would call for one processor acting as a data base manager controlling the simultaneous use of the data base by the other processors. The central data base could be complemented by additional classified overlays on the individual systems when required by security considerations.

In eliminating the data base redundancy, the large data base plan also reduces the number of storage devices needed. The one data base, being accessed by processors of varying classifications does present a security problem; however, this problem would be solved with the use of control-only data links between the unclassified central data base and processors of a higher security level.

ANALYSIS

With several meteorological satellites (DMSP, GOES, and TIROS) and with more sources for data (including radar data), the update of the data base will not necessarily be on a 3-hour (or any other) period. In fact, 1985 requirements dictate the assumption of data availability to update the meteorological data base on a sporadic (and for the most part almost continuous) time scale. Data base updates based on requirements and time limitations necessitate updating of universal data bases on the order of 10 minutes or less. The total transfer of data is an expensive requirement in terms of resources used. We propose the alternative where data are not necessarily duplicated from the master data base but rather all processors have access to a universal data base. One of the principal reasons for not doing this in the past is that the updating of this information by forecasters may impart information which is classified because of time and position. The solution as we see it is the existence of a classified data base which retains information updated by the forecasters which in effect acts as an overlay to the universal data base. As far as the user programs are concerned, they are accessing a single data base, and other users operating at the same classification level can receive the same information. In fact, the classified data base is small so excess time will not have degraded the system and a significant amount of resource has been saved.

One problem has been accessing data without betraying the location. We feel that the globe can be partitioned (e.g., WAC charts) and the data can be requested via control-only data links using the code which identifies one part in 512 (2^9 in terms of bits passed from a higher level computer with the actual protection of hardware for the actual access to the master data base).

An overlay is dependent upon the explicit link between geometric 3-space and the data base structure. Until this relationship is established, we won't know precisely how the overlays work. If the relationship can be determined a priori, then there will be a table established which, with knowledge of the order of transmission of data, identifies portions of the data base to be

substituted for what is being transferred. This table then points to the new data. Whether each new data set has to be checked for substitution or whether some intelligence can be employed to the arrival time of the key data again depends on the structure and the predictability of the arrival of the data. At some level it should be predictable, but not necessarily at the individual grid-point level.

Compared to the size of the total meteorological data base, the overlay portion is deemed to be fairly small. If it results from classified data input, it might be as much as 5%, but if it results from manual corrections, it will be extremely small.

SUMMARY/CONCLUSION

A single universal data base will be used which each computer system can access. Classified overlays will be used for a computer system based on security requirements. This design will require a minimum number of mass-storage devices compared to the present redundant data base concept. Each processor will have access to the data base either through two-way communication lines or a one-way communication line plus control data line depending on the security level.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A131-2, 3, 7, 8, A132-1, 4, 5, 7, 11, 14, A261-1 (e, k), A341-3, A931-1, A251-1

TRADEOFF TITLE

A13-2 Is the master data base different hardware than the "security level associated" data bases?

REQUIREMENTS/BACKGROUND

It has been decided that the central data base will be augmented by several classified overlays. While the central data base will be available for access by all processors, a classified overlay will be available only to systems of the same level as the system which built it. Because of the bulk nature of the classified data base, it may warrant different hardware.

DESIGN APPROACHES/CHARACTERISTICS

The design of the data base has been considered by A10-1.

ANALYSIS

The question here pertains to the bulk nature of the master data base and the fact that input to that data base will be in large data quantities. Contradistinctively, the classified data bases have multiple users with short messages and cyclic storage areas for communications. There is a good chance that a combination of fixed and variable head disks would be appropriate for the classified data bases but not for the master.

SUMMARY/CONCLUSION

A master data base will be on disks augmented by a mass-storage facility. Overlays to this data base will be established on disks at the appropriate security level.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

100 - Special Activities - All

300 - Emergency War Order Support - All

511 - Space Environment Support - OTHB Radar

RELATED SPECIFICATIONS

A113-3, A115-1, A233-1, A235-1

TRADEOFF TITLE

A13-3 What is the tradeoff between data compression versus uncompressed storage for satellite data?

REQUIREMENTS/BACKGROUND

Satellite data are presently mapped, gridded, and stored in the data base on a 1/64th mesh grid (3 nautical miles on a side). The information is "packed" so that six grid points are contained in each 36-bit word. As the requirements for processing more and more satellite data increase, so does the amount of mass storage it takes to contain these data. Another factor is the requirement for processing of higher resolution satellite data which will require even more storage space. Design alternatives which would reduce the amount of mass storage needed should be investigated.

DESIGN APPROACHES/CHARACTERISTICS

The relative value of raw data compression versus the direct storage of raw data is addressed in this analysis.

The following assumptions and approaches will be used in this study:

a. The bulk of this discussion will treat "data compression" as compression for the purposes of data ingest storage. Data compression techniques associated with various techniques of pattern recognition will be handled in a far more qualitative manner.

b. This tradeoff assumes the use of double density disk units that will store approximately 34 million (36 bit) words, e.g., UNIVAC 8433 disk unit, although it is recognized that other disks are also candidates.

c. Raw data, once ingested for a specific vehicle, will be gridded and mapped prior to the next contact with the same vehicle.

d. Total real-time conflicts can exist within a program. For example, two DMSP vehicle contacts can occur in exact time coincidence.

e. Current Site III or satellite relay capabilities were not considered to be limiting; i.e., the vehicle/AFGWC interface is working at optimum efficiency and the equipment in that interface is transparent to the AFGWC data system. (In the Block 5D era this would imply two 2.66 mbs links from each remote site.)

f. Vehicle orbit parameters are approximately assumed for 1) DMSP vehicles flying for early morning and noon area crossings and 2) TIROS-N flying for mid-morning and mid-afternoon area crossing. (This precludes the occurrence of simultaneous "major blind" readouts.)

ANALYSIS

The alternative to storing the satellite data in their present uncompressed form is to go to some compression technique (like a Fourier Analysis) and store only representative parameters in the data base. Besides allowing for a reduction in mass storage area needed, these "compression" parameters may have other direct applications to cloud analysis, thus having other favorable effects on computer resources.

More than reducing data storage space, the compression statistics may prove very useful in enhancing automated cloud analysis techniques. The work of Captain Sikula at GWC indicated that a compression rate of 100-to-1 could be achieved with the necessary cloud information still retained. There are two problems with applying Captain Sikula's work too quickly to the GWC situation:

a. Much costly development work is still left to be done in the area of relating satellite data compression statistics to cloud parameters;

b. Since the compressed data will be used for other analysis models (snow and temperature for example) as well as displays, a compression technique suitable <u>only</u> for a cloud analysis cannot be employed. It is estimated that the kind of general compression rate GWC could more likely obtain is 4 to 1.

This qualitative discussion will now be followed by a detailed five-part study of the costs involved in storing and compressing satellite data at GWC.

DMSP

The maximum expected single-station readout will occur when a vehicle exits its "major blind" which occurs between daily revolutions 1 and 6. At a maximum, this will cover four revolutions or approximately 400 minutes of data (one full record) recorded in the smoothed mode and 20 to 40 minutes of fine data (one full record). This can occur with a real-time conflict of the second DMSP vehicle. The second vehicle would be reading out 100 minutes of smoothed data and 20 to 40 minutes of fine data.

a. Vehicle 1 (Major Blind Exit)

1. Smoothed Data

Number of 36 bit words/readout = 2.66 mbs X 60 sec/min X 2.5 min per orbit of data X 4 orbits X 0.86 (Data Formatter conversion factor) ÷ 36 bits per word.

Total = 38 X 10^6 words/readout

2. Fine Data

Number of 36 bit words/readout = 2.66 mbs X 60 sec/min X 10 min of transmission time X 0.9 (Data Formatter conversion factor) ÷ 36 bits/word.

Total - 39.9 X 10^6 words/readout

b. Vehicle 2

1. Smoothed Data

?.66 X 60 X 2.5 X 0.86 ÷ 36

Total = 9.5 X 10^6 words/readout

2. Fine Data

Total = 39.9 X 10^6 words/readout

The requirements that are associated with DMSP and TIROS-N are:

a. Total coverage and processing of smoothed data from DMSP and TIROS-N (starting in 1978), and

b. Processing of three percent of available DMSP fine data in 1978 and ten percent in 1980.

The maximum data input will occur in 1980 when AFGWC is processing total coverage from the DMSP and TIROS-N smoothed source and ten percent of DMSP fine data. Raw storage is, however, constant even if total fine data processing is required since we assumed three percent could be gathered during a single orbit.

a. DMSP Smoothed Raw Storage

Vehicle 1	38×10^6 words
Vehicle 2	9.5×10^6 words
Total	47.5×10^6 words

Two dedicated double-density disk units (34M words each).

b. DMSP Fine Raw Storage

1978

39.9×10^6 words/readout X 10 readouts day X 2 vehicles X 0.03 (1978 requirement). Total = 24×10^6 words. One dedicated double-density disk unit.

1980

39.9×10^6 words/readout X 10 X 2 X 0.1 (1980 requirement). Total = 80×10^6 words 39.9×10^6 words/vehicle for maximum readout per vehicle. Note: Allowing for 75 percent of the maximum two-vehicle readout gives a total fine raw storage of: 60×10^6 word/2 vehicles. Two dedicated double-density disk units. This much raw fine storage would also be sufficient for total fine data processing. The 75 percent assumes that total real-time conflict will not occur on file data because of the selectivity used in recording specific areas of high interest.

TIROS-N

Due to the probability of real-time readout conflicts, TIROS-N will require separate storage from DMSP. Storage requirements for smoothed data will be identical to DMSP. No requirements exist for TIROS-N fine data processing.

GOES

A single GOES readout in Mode A requires 51 X 10^6 words of mass storage or two dedicated double-density disk units.

TOTAL MASS STORAGE COST FOR RAW DATA

The total number of double density disk units ($36,000 each for the UNIVAC 8433) required for raw data input is eight plus a control unit ($100,000 each). Allocating one disk controller and a pair of disks for backup gives a total price of $560,000.

DATA COMPRESSION COST

The cost associated with the compression of raw data utilizing a two-dimensional Fast Fourier Transformer is approximately $0.5 for each 2.66 mbs input source (hardware only). At a minimum, this would require two units plus one backup to process the smoothed data from a single vehicle ($1.5M). Facilitating multivehicle support within and between TIROS-N and DMSP, as well as handling fine and smoothed data simultaneously, would further increase the cost. Note: This cost is the data compression only and does not address additional costs associated with data reconstitution.

SUMMARY/CONCLUSION

The cost for storing the satellite data in raw form on double-density disk units (34M words each) is far less than the cost associated with the implementation of data compression. The cost for storage in raw form is $560K compared to several million for raw data compression. Furthermore, it has not been shown at this time that the compression parameters can significantly enhance other functions (cloud analysis).

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

- 113 - Special Activities - Program D
- 120 - Special Activities - ZOOM Use
- 406 - Environmental Support - Satellite Imagery Dissemination
- 408 - Environmental Support - Interactive Processing and Display System
- 602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A452-1 through A452-5, A114-1, A515-4, A313-12 through A313-17, A234-1, 2, A441-1 through A441-3, A442-1, A443-1

TRADEOFF TITLE

A13-4 What is the tradeoff between more storage area and data packing in the meteorological data base problem?

REQUIREMENTS/BACKGROUND

The present data base format encourages the packing within a single word of as much data base information as is possible. The primary consideration is saving of storage area, both on the mass-storage device and in the core of the computer. But as more storage and core area become available at cheaper prices, computer time spent in the extra packing and unpacking may be more significant.

DESIGN APPROACHES/CHARACTERISTICS

The two extremes in this case are to continue to encourage packing in the data base or to prohibit any packing of data. The first case assumes that storage area must be conserved at all costs and the second one uses as much storage as necessary in order to save any possible compute time.

ANALYSIS

The primary factors which reflect on this situation include:

a. More mass storage available
b. More and faster core storage available
c. More preformatting or massaging of data.

This indicates that the future situation will be more complicated than the present one which encourages data packing to save mass and core storage. More core and mass storage and faster access times suggest less packing is necessary but faster core says that packing could be handled more effectively. It comes down to looking at each individual function and deciding what the tradeoffs would be.

Prediction models like ZOOM and AWSPE could lend themselves to the unpacked format rather well since the grids are small in size and data handling is not

a problem. Functions dealing with the 15 cloud layers per grid point and the very dense satellite data face other problems since it would take massive amounts of additional core to accommodate them.

If the data are preformatted or massaged to make it more suitable for individual functions, maybe even those handling cloud and satellite information can be made to handle it in an unpacked form. The question is not a simple one, for each function there needs to be a tradeoff between computation time and core with a constraint that requirements must be met.

SUMMARY/CONCLUSION

We will allow independent or unique pieces of data to be stored separately and will pack data which is closely related and occurs in large quantities. This decision reflects the complexity of the hardware situation where mass storage will be available at cheaper costs and computer power will also be reduced in price. It strikes a median between these two costs.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A115-1, 2

TRADEOFF TITLE

A13-5 Should discrete satellite data storage structure be used for analysis and image distribution functions?

REQUIREMENTS/BACKGROUND

Once satellite information has been assimilated into the GWC data system it has two primary uses: analysis algorithms and image distribution functions. Because of the different nature of these two applications, there may be a real need for unique data bases to exist.

DESIGN APPROACHES/CHARACTERISTICS

The present approach is to map and grid all satellite data to a central data base in both polar steographic and Mercator projections. Data are then extracted from this storage area and modified (if necessary) for the specific application. The alternative to this is to construct two types of software data bases designed either to contain information for analysis models or for displays. This approach would allow for the preprocessed, prefiltered, or otherwise modified data to be stored in that form in the data base, already tailored to a specific need.

ANALYSIS

The redundant storage alternative suggested by this tradeoff offers the possibility of employing two techniques which may be advantageous to analysis functions:

a. Satellite data preprocessing before data base storage during non-critical time periods,

b. Satellite data statistical reduction by hardware before data base storage.

Many satellite data will be ingested and analyzed in the future within the sprint sunstream where there is no overhead time available for preprocessing; hence, the first point offers no advantage. Data reduction by hardware is not feasible until development has shown ways that the reduced parameters can benefit analysis functions; this has not been accomplished.

Neither the requirements which would justify nor the advantages derived from the separate storage of satellite data to be used for analysis or display functions have been identified.

SUMMARY/CONCLUSION

GWC should continue with its present plan to store all satellite data to be used by both display and analysis functions in a single, central data base until such time as another direction seems advantageous.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

- 113 - Special Activities - Program D
- 120 - Special Activities - ZOOM Use
- 406 - Environmental Support - Satellite Imagery Dissemination
- 408 - Environmental Support - Interactive Processing and Display System
- 602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A115-1, A241-6, 9, A452-1 through A452-5, A515-1, 2, 4

TRADEOFF TITLE

A13-6 Should WWMCCS data base be distinct or combined with general data bases?

REQUIREMENTS/BACKGROUND

To satisfy the requirements established by WWMCCS, a data base different from the one presently at GWC will be required. It must be established whether this new data base will be separate and distinct or combined with other general data bases.

DESIGN APPROACHES/CHARACTERISTICS

The WWMCCS data base can be designed to be a unique and separate area, suitable for WWMCCS needs only, or it can be combined with a global representation of all meteorological parameters of interest to the modernized base weather station as well as internal GWC forecasters. The second suggestion may provide a savings in mass storage area (by cutting down on some redundancy), but it will pose a significant problem involving planning and integration of ideas.

ANALYSIS

We think the concept of a WWMCCS data base should be generalized to be a user interface data base which includes a global representation of all meteorological parameters of interest to the modernized base weather station, WWMCCS users, as well as internal GWC forecasters. The structure should be developed hand-in-hand with the language for its use. It should also involve the availability of preformatted human user or machine compatible messages for presenting the data and a hierarchical request structure encompassing the time, space, and meteorological parameter vectors. A User's Guide should be immediately prepared with updates accommodating user requests so that GWC design accommodates rather than is dictated by user requirements. User bulletins should be issued to increase the acceptability and usability, and user agency solicited feedback should provide a basis for optimum capability.

SUMMARY/CONCLUSION

Combine the WWMCCS data base with a global representation of all meteorological parameters of interest to the modernized base weather station as well as internal GWC forecasters. This decision will meet the WWMCCS requirements and will tend to eliminate data base redundancy and storage requirements.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

200 - Command and Control Systems - All

409 - Environmental Support - Operation Security

RELATED SPECIFICATIONS

A115-1 through A115-3, A131-1 through A131-9, A341-2, 4, 5, 7

TRADEOFF TITLE

A13-7 To what extent should application programs know of location and structure of data?

REQUIREMENTS/BACKGROUND

In the process of retrieving or storing data in a data base, it may enhance the I/O process or the computations done by the applications program if it knows about the location and structure of the data. The amount of prior knowledge needed by the applications program should be determined.

DESIGN APPROACHES/CHARACTERISTICS

The two extremes include giving the applications program no knowledge of the location and structure of data within the data base or seeing that it understands all of this information. The first approach is more likely to mean that data base changes will be transparent to the user program compared to the second case; but, it also means the data base handler will necessarily be more complicated.

ANALYSIS

There are many changes which the data base will undergo which make it very undesirable for an applications program to expect any particular location and structure for data. Some of the primary factors producing these changes include:

a. Gradual expansion of the data base due to storage of new or different parameters.

b. Use of "overlay" data bases to alleviate security problems.

c. Staging techniques for storage devices,

d. Preprocessing or reformatting of data to meet specific needs,

e. Use of filtering of data in place of memory search.

Among other complications, these new procedures and the fact that great amounts of mass storage will be available far cheaper than before means a large, redundant, and dynamic data base. In short, it would be a time-consuming procedure for an applications program to predict the location and structure of the data it needs. To meet requirements the data need only be delivered to the function in the proper order and format by the data base handler.

SUMMARY/CONCLUSION

No knowledge of location and structure of data within the data base is needed by applications programs. This asserts that only the data base handler need have detailed knowledge of the exact data base format.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A132-17, 18, 20, 21, A332-1

TRADEOFF TITLE

A13-8 Should a distributed data base concept be allowed?

REQUIREMENTS/BACKGROUND

One concept of data base design involves breaking it into sections which relate to their functional origins or usages and dedicating the storage to individual processors. Three divisions, for example, might be associated with satellites, models, and conventional observations. This "distributed" data base concept is an option opposed to the central data base theme.

DESIGN APPROACHES/CHARACTERISTICS

The distributed data base concept is in conflict with the central data base design which has already been adopted (see A15-2 and A15-9).

ANALYSIS

(See A15-2 and A15-9)

SUMMARY/CONCLUSION

There will be a universal data base with classified overlays. Beyond this the exact structure is yet to be determined.

RELATED REQUIREMENTS

This Trade Study is releated to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A131-2, 3, 7, 8, 9, A132-1, 4, 5, 9, 11, 12, A261-1 (e, k), A341-3, A251-1

TRADEOFF TITLE

A13-9 Will the present meteorological data base structure accommodate current requirements and what are the alternatives?

REQUIREMENTS/BACKGROUND

The present meteorological data base structure at GWC is the product of an evolving set of requirements. The result is that it may now resist more growth and not be able to adjust to even more requirements. Its adaptability to change should be investigated.

DESIGN APPRAOCHES/CHARACTERISTICS

The opposite approaches are straightforward:

a. Keep the present structure for the meteorological data base.

b. Modify the meteorological data base structure so that it can more easily accommodate new requirements.

ANALYSIS

The structure of the data base is based on three vectors: a time vector, a vector in which each element is a box-3 space and a vector which has each element the value of meteorological parameter in that space at the time. The present data base structure philosophy accommodates the current data, but will not necessarily accommodate post-1977 versions. Even though the three important vectors remain the same their nature changes.

Starting first with the time vector, in the present data base the structure depends to some degree on the assumption of only a few convenient intervals (older data are purged). It assumes purge of all data simultaneously for a given time and point in 3-space. It assumes no two sets of data can be represented at a single point in time. With the existence of three input

satellite systems updating the data base when the data are available and the possibility for purging only part of the data for a given point, the time dimension takes on more of a continuous nature rather than being discrete and cyclic.

The dimension which describes a solid in 3-space also is changing in the era of the new architecture. Presently only one grid scale is accommodated with all others treated as an exception. With the mesoscale support of tactical systems sometimes for prespecified target areas, it seems the data base must accommodate a variable grid structure or at least provide an equally simple and efficient structure for each system as well as a useful interrelationship.

We envision the parameter set associated with a single-space time point accommodating more variables, but on the other hand allowing a wider variation in the number of variables represented at a single point. This may be due to the need for identification of data source and data reliability. Observation is needed in the probabilistic line of sight problem, for example. We see the expansion of trend variables or trend statistics as possible parameters. The new structure must accommodate an expansion, even though we cannot currently identify exactly what that expansion will be.

There are cascading effects associated with the changes mentioned above. For example, we can no longer necessarily afford to automatically duplicate the meteorological data base on all systems if the time update is on an almost continuous scale. The structure of the system may be so complex in storage that both users and user programs must have a simpler visualization of the structure than that actually incorporated. Thus, data base management routines and an "apparent structure" must be developed.

If we are unable to update data bases, a new security problem is imposed if all systems are to work off of a single data base. A potential solution is the use of overlap data bases which are classified and contained within a secure environment as well as a concept of requesting data from a higher to a lower level.

The final consideration involves the availability of different hardware capabilities in the 1982 era. Manufacturers have incorporated staging techniques which allow data to be moved from slower to more rapid access devices (e.g., from tape to disk to auxiliary memory to main memory). Further we can buy great amounts of mass storage much cheaper than we ever could before thus allowing more efficiency in addressing and access at the cost of a little more wasted memory.

The additional storage and the availability of fast-array processors suggest preprocessing into applications-peculiar formats. It suggests redundancy for overlap storage to ensure rapid sequential read for contiguous areas. It may even imply sequential read and filter as opposed to memory search.

SUMMARY/CONCLUSION

It is SDC's opinion that simply modifying the current data base structure is an undesireable approach in formulating the new meterological data base. We think that a hierarchical gridding system (such as the Navy's spherical triangle system) should be investigated and recommended. The data base structure should then be optimized to fit the application.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A131-1 through A131-9, A132-1 through 24

TRADEOFF TITLE

A13-10 What preformatting of data can be accomplished during nonresource critical periods to accommodate faster processing at run time?

REQUIREMENTS/BACKGROUND

Before a model or other function can make use of information stored in the data base, it is often necessary to preprocess or massage the data, putting it in a form more adaptable to the specific use. If this preformatting can be accomplished prior to the function's execution, then run time may be reduced during resource critical periods.

DESIGN APPROACHES/CHARACTERISTICS

The present mode is to store a single representation of all data in their simplest form in the data base. Any modifications to the data base (no matter how simple or complex) are then left to the user program to perform. The opposite approach would consist of storing all data in the data base in the form that they will be used in (whether preformatted, filtered, or otherwise).

ANALYSIS

At times it is possible to represent the same quantity in several different ways for different needs. A trivial meteorological example would be to list temperature as either Kelvin, Centigrade, or Fahrenheit.

If these simple conversions could be made before the models ran which used them, we could save some computation time when it is needed most. The probable availability of adequate mass storage now makes preformatting even more feasible.

One obvious place where preformatting shows promise involves the handling of observational data. They are primarily used as input to the analysis routines and they may consist of up to 120 parameters packed in 30 words. Decoding this for some particular information can be a big job for an analysis routine and maybe one that can be done prior to its execution.

Analyzing satellite data for cloud information is a tedious procedure (due to the large data amounts) and most of it might also be done earlier-preprocessed and preformatted for use by the cloud analysis routines.

An example of the potential gain due to preformatting concerns the conversion between the grid that the AWSPE works in (53 x 57), and the data base grid (47 x 51). (The large area is necessary to minimize boundary instability problems.) The smaller grid is a point-for-point subset of the larger, but still the conversion between grids takes about 10 minutes SUPS per execution of the AWSPE. At the present time the AWSPE is scheduled to closely follow the execution of the analysis routines so that no overhead time is available for preprocessing. Future systems however, with faster computation rates and data base handling routines adept at data formatting, make such preprocessing of data more feasible and attractive, benefitting routines like the AWSPE.

SUMMARY/CONCLUSION

Preformat data for specific uses when it is cost effective to do so, storing both the initial and preformatted representations in the data base.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

200 - Command and Control Systems - All

406 - Environmental Support - Satellite Imagery Dissemination

RELATED SPECIFICATIONS

A132-22

TRADEOFF TITLE

A13-11 What generalized data structuring is warranted (e.g., communications output messages)?

REQUIREMENTS/BACKGROUND

The factors which warrant generalized data structuring, for example in communications output messages, must be established.

DESIGN APPROACHES/CHARACTERISTICS

(See ANALYSIS)

ANALYSIS

There are two principal reasons for generalization: a) to enhance recognizability of messages for security checking; b) to simplify the human interface, thereby reducing the chance for human error and simplifying the training for human interface. Other reasons, though not as important, are simplifying the programming task for software development and documenting easy-to-understand standards as a means for interface definition control. Based on these reasons, the primary candidates are input and output communications messages, all human interface messages and input formats, and the definitions of programmer interfaces with modules and data structure. All interfaces between components are candidates as well as interfaces between distinct functional areas (e.g., satellite data processing, communications, network control).

SUMMARY/CONCLUSION

Reasons for generalizing data structure:

a. Simplicity for security checking

b. Simplicity for reducing human error

c. Simplifying programming

d. Easier documentation

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

115 - Special Activities - Agency B

200 - Command Control Systems - All

406 - Environmental Support - Satellite Imagery Dissemination

RELATED SPECIFICATIONS

A132-21, A461-1

TRADEOFF TITLE

A13-12 What are the data base complications in using an associative processor for data management?

REQUIREMENTS/BACKGROUND

The complex job of data base management may be adaptable to an associative processor. The possibilities and complications of this should be studied.

DESIGN APPROACHES/CHARACTERISTICS

The possible approaches to a data base management processor include either a conventional processor or an associative processor assisting its host.

ANALYSIS

Data base management as it is currently known is an I/O-bound function. The operations performed on the data take far less time than the ability to search and read the data. If we expand the definition of data base management to include the application-specific process of optimum formatting, enhancing the capability for search-by-value becomes even more key.

The natural inclination is that an associative processor would not efficiently do the total data base management job, but the associative processor along with a host might.

There are some scheduling implications resulting from the use of the associative processor for the data base management function. The number of associative processors in option E of table 10.11 is based on our estimate of worst-case conflict between the five major models. If data base preprocessing were linked to the running of another time-critical application program, we would have to avoid the conflict. Therefore, the associative processor and its backup must be dedicated to the task of assisting the data base manager.

The hardware cost of this approach is approximately $1.5 million. This large sum must be weighed against the ability of the associative processor to decrease response time in the network (faster preformatting and search) and to offload its host. In addition, the associative processor's search capabilities allow far

greater freedom of data base structure, which will be very important in trying to meet user (e.g., WWMCCS) response-time criteria. This flexibility is also key to assimilating the multitude of satellite sensor data into a central data base, because of the varying grid sizes between sensors and the nonuniform time spaceing between samples of the atmosphere.

SDC does not feel, however, that the $1.5 million hardware cost can be quantitatively justified at this point in time. The use of an associative processor should be reviewed as requirements harden and as the future data base structure becomes more well defined.

SUMMARY/CONCLUSION

An associative processor is not cost-justifiable at this time for the data base management job. Therefore, a conventional processor will be used without associative processor assistance.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

None

TRADEOFF TITLE

A13-13 Is there an application for a Data Management System produced by a vendor (especially consider UNIVAC 1100 DMS)?

REQUIREMENTS/BACKGROUND

The Data Management System (DMS) in use at GWC is the result of in-house development but may lack the sophistication to adapt to radical data base changes. The possibility of using a vendor-produced DMS in this area should be investigated.

DESIGN APPROACHES/CHARACTERISTICS

(See ANALYSIS)

ANALYSIS

Vendor-produced data management system packages are oriented towards commercial applications. That is, vendor DMS packages are targeted for the efficient processing of extremely large data bases for applications which have low transaction rates. DMS packages provide capabilities to design and structure a data base and capabilities to access data from such a data base. Data accessing statements are, or can be, relatively independent of Higher Order Languages (HOL) which are used to code the programs which use this data. However, current vendor implementations require a host HOL, usually COBOL. Such is the case with the UNIVAC 1100 DMS. Additionally, protection from unauthorized access to data or changing of data, if provided, is oriented for commercial applications. The vendor-provided DMS provides high transaction rates combined with constant demand and military security.

Design decisions which have been made and design options which require further study indicate that the utility of any vendor-supplied DMS package would be severely limited. A single universal unclassified data base with classified overlays where the storage and processing options for the universal data base include retrieval from mass-memory storage facilities or disk by an associative processor, one-way data paths for security, and assignment of jobs to specific processors and their associated data base files to the specific processor disk by Network Control, limit the utility of a vendor-supplied DMS to effecting the

data management interface between the application programs operating on the processor(s) selected by Network Control and the disk(s) attached to the selected processor(s). The possibility of multiple hardware vendors could further limit the utility of a vendor-produced DMS package in that it could reduce the number of processors on which the DMS package could be used. A major portion of the Data Management System required for AFGWC is retrieval from (or restoration to) the centralized data base unclassified files required or processed by applications programs and any associated classified overlays. Development of software to effect such an interface between the data base and a switching and routine system with stringent security features and Network Control must be done for AFGWC.

The UNIVAC 1100 Data Management System received special consideration in that some tradeoff comparisons between UNIVAC 1100 DMS and the Data Management System currently in use at AFGWC were attempted. Some of the advantages which the UNIVAC DMS provides include: vendor maintenance of the data management system; a separate data base design or structuring language, the Data Definition Language (DDL); provision for a variety of search structures; central control of all access to the data base through the Data Management Routine (DMR), and rollback and recovery capabilities for restoration of the data base after loss of integrity. However, UNIVAC 1100 DMS is a general-purpose DMS targeted for commercial users as opposed to the data management system developed at GWC, which is tailored for current GWC requirements and which should be more responsive to GWC future needs. One additional point which applies to all vendor packages, not just UNIVAC 1100 DMS, is relevant. Namely, that vendor scheduling for fixing of errors or updating the DMS to reflect changes in the Operating System or changes in the data base itself cannot be as responsive as can be provided by GWC personnel.

At this point in the GWC study, no compelling reasons are evident which would cause GWC to deviate from the use of FORTRAN for development of GWC applications programs. Many reasons continue to encourage the use of FORTRAN as the standard basic language for development of GWC applications. Continued use of FORTRAN should minimize software breakage in that programs currently written in FORTRAN which continue to be valid can be transferred to new computers and/or new operating systems at less cost than programs developed in other languages. New pro-

grams developed in FORTRAN will be more portable than programs developed in other languages in that they can be transferred to new computers in the post-1982 period. With continued use of FORTRAN as the basic software development language, training costs can be contained in that less training will be required and better training at lower cost has evolved with the continued use of FORTRAN. FORTRAN compilers provide for generating highly efficient object code for arithmetic, relational, and control statements. Additionally, continued use of FORTRAN provides more leeway in hardware considerations in that FORTRAN compilers have been developed, or are under development, for the array processors.

Assuming FORTRAN will continue as the basic GWC language for development of applications programs and assuming that the previous discussion doesn't preclude a COBOL-hosted DMS such as UNIVAC 1100 DMS from further consideration, the next thing to investigate is how much software (FORTRAN applications and COBOL-hosted DMS) would interface. In order to avoid confusion factors in such an investigation, the desirability of having a centralized run-time Data Management Routine which controls all access to the data base and the desirability of having this run-time DMS interface with a description of the pertinent data base components (schema) is taken for granted. Options for effecting such an interface include:

a. Writing a series of small COBOL programs which contain the Data Manipulation Language (DML) statements required for the data base access and writing the calls to the COBOL programs in the FORTRAN applications programs (much as the calls to access data now appear). The variations of possible combinations of DML arguments and statements are numerous, and the variety of ways an applications programmer might use to assemble the necessary data is also numerous. The possibilities range from an overwhelming number of COBOL programs and even more subroutine calls from FORTRAN programs to a few COBOL programs oriented towards DML logical subcategories (or possibly oriented towards specific portions of the data base) with multiple entry points and long parameter (argument) lists. Although the subroutine call-subroutine entrance-subroutine exit linkages between COBOL programs calling COBOL subprograms are the same as the linkage between FORTRAN programs calling FORTRAN subprograms, this approach might cause some

problems in that both FORTRAN and COBOL expect the MAIN program to be written in their respective languages.

b. Writing one COBOL program for a given processor-disk configuration which implements all data base interface processing using DML statements and transfers control to the FORTRAN applications program which is coded as a FORTRAN subroutine. In effect, the COBOL main program would function as the data base interface and the scheduler or control program. This approach seems more straightforward from a data management point of view. However, the impact of changing all the FORTRAN programs to subroutines called from a COBOL main program, and the likelihood that a scheduling program written in COBOL would be too inefficient, detract from any appeal that this approach might have. A more important consideration is whether or not the AFGWC data processing jobs would function well within such a structure.

c. Another possibility suggested for interfacing FORTRAN applications programs with a COBOL-hosted data management system calls for the writing of a COBOL program with DML statements in it which reflect the type of DML action required by FORTRAN applications programs. Since DML statements are transformed by the DML preprocessor into calls to the Data Management Routine (DMR), the applications programmer could hand-copy the DMR subroutine calls into the appropriate place in the FORTRAN application program. In addition to programming manpower inefficiently applied to copying the calls, the debugging of programs constructed in such a way is far from easy.

The approaches described above for interfacing FORTRAN applications programs with COBOL-hosted Data Manipulation Statements all appear cumbersome and time-consuming from a program development point of view. They create an extra, unnecessary run-time linkage overhead not existent in the current system and not required for a FORTRAN-hosted Data Management System, and provide no improvement over the current system.

Since data bases and the structures of data bases are subject to change, the interface of FORTRAN applications programs with COBOL-hosted data base management systems creates an ongoing problem for programming personnel and an ongoing

source for software reliability programs. The problem naturally arises because COBOL host DMS systems are not intended for interface with FORTRAN programs. When changes to the data base or the data base structure are made, a self-contained COBOL application and DMS system merely needs recompilation to ensure that the proper structures exist for receipt of the data by the applications program. Such would not be the case for a FORTRAN program. Each time a data base change and corresponding COBOL recompilation occurred, manual changes might be required for the FORTRAN program with a requirement for program testing each time a change was made.

The nature of the AFGWC data processing job, the desirability of continued use of FORTRAN for applications programs, and the design decision for a single universal data base with classified overlays all dictate that a special-purpose Data Management System with characteristics which reflect AFGWC requirements and priorities be developed for AFGWC.

SUMMARY/CONCLUSIONS

A vendor-produced data management system will not fit AFGWC requirements. The UNIVAC 1100 DMS requires COBOL as the host language and would degrade processing even more than a vendor-produced data management system which provides for FORTRAN as the host language.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

None

TRADEOFF TITLE

A13-14 Is there a need to record access and usage statistics?

REQUIREMENTS/BACKGROUND

Data base access and usage statistics may be a valuable input allowing GWC to do internal tradeoff studies which would determine when fields/models have outlived their usefulness. Presently these statistics are not available in an automated mode.

DESIGN APPROACHES/CHARACTERISTICS

In the present mode no data base statistics are collected. The alternative to this is to provide the ability to collect necessary data base usage statistics for internal tradeoff studies. This becomes even more feasible with the design decision having been made to have a centralized data base with classified overlays. This simplifies the bookkeeping problem.

ANALYSIS

Collecting data base usage statistics has been a goal long sought after by GWC. Increased run time and other operational problems has made this collection impossible in the past but it will be part of the reentrant data base handler package being developed now. The need for these statistics arises from the fact that the demand for certain portions of GWC's data base varies with time. If a need disappears or is sufficiently low, the data base and model that built it may be candidates for deletion. This would save not only mass storage but possibly computation time. The present method of making this determination is manual, time-consuming, and far from exact.

SUMMARY/CONCLUSION

The ability to collect necessary data base usage statistics for internal tradeoff studies should be provided.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

600 - General - All

RELATED SPECIFICATIONS

A132-17

TRADEOFF TITLE

A13-15 What are the tradeoffs between a demand versus service versus update interface with the central unclassified data base?

REQUIREMENTS/BACKGROUND

The question is whether the central data base manager should:

a) send data only on request,

b) broadcast changes to the data base when these reach a certain level of significance, or

c) periodically broadcast updates.

DESIGN APPROACHES/CHARACTERISTICS

The two opposing points of view are summed up by these statements:

a. Only the simplest of read/write access capabilities of the unclassified data base are required by the average user.

b. The master data base management capability shall afford a variety of options, including:

1) obtain data by location

2) obtain data by value

3) search upon update based on thresholds

4) initiate action based on update

ANALYSIS

We think that the interface with the general unclassified data base need not be restricted. However, we encourage strict control over this freedom. The principal usage of the base should be one of requesting data when they are needed to ensure up-to-date information and a minimum of interaction with the data base manager. In cases where the data base must be monitored to search for threshold violations or increments in parameter values, the data base manager should accomplish these requests by notifying the network controller of needs

to activate certain capabilities. It may also necessitate updating certain classified data bases; however, no such examples of this action can currently be identified. It is important to develop a master data base users' language and a set of options which can be available for use by the individual routines of the system. We believe that response afforded by a master data base management subsystem as well as the transfer of high-speed data will accommodate any user's timing requirements (e.g., in the case of the advanced prediction model, preprocessing can set up vector forms and auxiliary memory to facilitate rapid handling by array type processors).

Updating in the master data base requires design emphasis. We suggest updating portions of the data base while having previous counterparts available for simultaneous requests. Upon completion of the update of a small portion this will be made to supersede its predecessor data. The data base management routine will always know what it should treat as current and will respond to requests accordingly.

SUMMARY/CONCLUSION

The master data base management capability shall afford a variety of options, including:

(1) obtain data by location

(2) obtain data by value

(3) search upon update based on thresholds

(4) initiate action based on update

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A132-17

TRADEOFF TITLE

A13-16 Is a data-oriented language warranted for use at AFGWC? If so, what should be the nature of the language?

REQUIREMENTS/BACKGROUND

The primary applications computer language used at GWC is FORTRAN. It has obvious shortcomings when it comes to data transfer and handling. It may be possible to augment or replace FORTRAN where these processes are concerned.

DESIGN APPROACHES/CHARACTERISTICS

The following approaches have been considered in this study:

a. Use FORTRAN exclusively even where data handling is concerned.

b. Replace FORTRAN by a data-oriented language (like COMPOOL specification statements) where data handling is concerned.

c. Replace FORTRAN entirely with a language (like APL) which provides adequate capabilities for data handling and computation.

d. Augment FORTRAN with a language that would complement its data-handling deficiencies.

ANALYSIS

Data management statements which explicitly represent the data management actions desired by the data base user provide for easy use, easy understanding, and easy modification. This improvement over the present data base access method derives from the explicit form of the data manipulation statements in that the user defines in such a statement exactly what he wants done with a specific set of data (rather than setting up a subroutine call to a data management routine where the data reference is implicit and must be constructed using documentation describing the call and the parameters). These program development advantages become system advantages which facilitate standardization and management control of both the data base and programs which access the data base in an environment such as GWC where there is an ongoing requirement for the data base, a require-

ment for modification of programs which use this data base, an immediate requirement for the development of additional applications programs which access the data base, and a high probability for long-range development of additional programs which utilize the GWC data base.

Data-declaration statements oriented for design and construction of the data base provide for improved data processing in a manner similar to the data manipulation statements discussed previously. The data base controller or the data base design maintenance group are provided with tools (data base design declaration statements) which facilitate the definition and construction of a data base specific to the needs of the system of data base users.

Continued use of FORTRAN for development of AFGWC applications programs is probable and desirable. Such use will minimize reprogramming of current applications software, given that most of the current programs are written in FORTRAN, and increase the transferability of future applications software.

The design decision (see A16-3) that the GWC data base management system be developed at GWC and the conclusion that FORTRAN will continue to dominate as the language for applications software dictate the development of support software to process data-oriented statements assuming a tradeoff conclusion that a data-oriented language is warranted for use at AFGWC and further assuming an AFGWC commitment to implement such a language. The structure and capability requirements of such support software therefore becomes relevant to this tradeoff analysis.

Independent of decisions regarding retention of the current system, a requirement would exist for a processor (or processors) that is capable of receiving mixed Data Management Languat (DML) and FORTRAN source statements which: a) describe (for design or construction) the data base, or b) constitute a FORTRAN application program with a capability to refer to data base data using DML statements. Representative processors capable of making such transformations include: a) a preprocessor developed by General Research Corporation, ENLODE, which combines some elements of a higher-order language suited for specifying Ballistic Missile Defense (BMD) engagement logic with elements of a higher order, data oriented language suited for translation to FORTRAN source code which effects the interface with a centralized BMD data base; and b) the

UNIVAC 1100 DMS preprocessor which accepts combined Data Manipulation Language (DML) and COBOL source statements and produces (COBOL source statements which include subroutine calls to the Data Management Routine (DMR) in order to implement the action of the DML statement. Such preprocessors are not overly complicated, and development of like processors can be accomplished using standard compiler development context analysis, syntax driven, or macro processing techniques.

Development of such a preprocessor using macro processing techniques is especially attractive in that in addition to implementing the desired data management extension to FORTRAN, it provides an ongoing capability to supplement FORTRAN through the use of MACRO declarations and MACRO calls. Such a capability could be used to add new data management capabilities to the baseline data management language, provide AFGWC language extensions to FORTRAN which would be consistent with structured programming (e.g., IF-THEN-ELSE, DO WHILE, and CASE Macros), or to develop Higher Order Language constructs suitable for the analysis, development, and/or construction of GWC systems. An operational example of this type of processor is the SDC-developed AMPLE (an Adaptable Macro Processor for Language Extensions) which processes MACRO declarations written in FORTRAN, retrieves canned FORTRAN Macros from a Macro library and translates programs containing AMPLE MACRO calls into FORTRAN source programs. A macro processor of this type could be used for developing experimental language forms suitable for consideration as Higher Order Language forms tailored to GWC processing needs.

A baseline specification suitable for use in developing a data-oriented language for AFGWC is available. The CODASYL data base task group has produced specifications for a data-definition language which should be an industry standard and specifications for a data manipulation language (which augments COBOL) which can serve for guidance in the development of a data manipulation language to augment FORTRAN. The CODASYL data base task group recommendations for a data-oriented language are the result of a long and concerted effort by leaders in data management techniques. Their specification represents the best in current thinking on language forms relevant to present-day hardware.

SUMMARY/CONCLUSIONS

A data-oriented language is warranted for use at AFGWC. This language should augment FORTRAN for data handling and should provide tools for data base construction. The CODASYL data base task group language specifications are recommended for use as a baseline specification.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A332-1

2.0 DATA TRANSFER AND ROUTING

TRADEOFF TITLE

A20-1 How does intercommunication take place within the GWC architecture?

REQUIREMENTS/BACKGROUND

The requirements for intercommunication are driven by three basic things:

a. the security requirements for control-only data flow, one-way data flow, and authentication coded data paths within the system;

b. Processor flexibility to commonly seek data from a variety of data bases thereby increasing the alternatives in resource allocation; and

c. satisfaction of contractor maximum distance criteria for component connection.

DESIGN APPROACHES/CHARACTERISTICS

The design approaches are obvious if we are to meet the requirements. There must be rapid switching on the order of seconds from one security level to another, these must be a way of communicating control information from a higher security level resource to a lower level resource, and the capability must exist to rapidly communicate bulk data from lower to higher security levels.

ANALYSIS

The problem at GWC is one of authentication protection against inadvertent exposure due to hardware failure or software error. The SDC approach has been the use of coding using some version of an encoding chip which renders data unusable and unrecognizable in the event of inadvertent transfer to the wrong recipient. The nonrecognition of code actually prevents remaining data from being transferred, and thus this is, in actuality, an authentication scheme; however the encoding of data protects against double failures. The difficulty with the chip approach is that routing must take place after decoding if control information is inherent to the data, or routing instructions must exist completely independent of the data, say, over a control-only data link. Other authentication schemes depend on switching and the physical problems of initiating a new link rapidly.

For control-only data lines the options exist of fixing the bandwidth checking procedures, or allowing operational establishment of checking procedures. We have chosen the later approach.

In terms of switching flexibility, we have decided to simplify the problem by only allowing automatic switching between processors and the data base. We further feel that if processors are only required to interface with contiguous data bases (either 1, 2, or 3 such data bases depending on the physical position of the processor within the system), this still allows the flexibility to meet the requirements.

SUMMARY/CONCLUSIONS

Two parallel upgrade communication links as well as the control-only data link provide the necessary capability. A "wagon wheel" type linkage. cuts down on number of lines and channels. Processors are allowed to move between data bases by virtue of their permanent connection to all data bases (but with authentication compatibility only with one).

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A20-1 through A294-2

TRADEOFF TITLE

A21-1 What is the nature of a control-only data connection?

REQUIREMENTS/BACKGROUND

To accommodate the network control task and requests from a higher level machine to an unclassified data base, it is necessary to provide a data link from a higher level machine to a lower one.

DESIGN APPROACHES/CHARACTERISTICS

(Also see A21-2)

Besides using a manual request (which would not meet the time requirements), the only other way of providing data/action would be without communication (i.e., preplanning and scheduling all upgrade activities). We felt this to be a greater problem than trying to design a "control-only" data link.

ANALYSIS

It has been established that under specific conditions some control information may flow from the high-level perimeter to the low-level perimeter. One possible arrangement allowed for an acknowledgement (ACK) or negative acknowledgement (NAK) to be returned from the high-level periphery to the low-level periphery. The suggested scenario screened a string of ASCII characters (eight bits each) for these allowable responses. That is, two characters out of the total of 2^8 (=256) characters is considered an acceptable ratio. Allowing two characters to be returned also means that should an accidental error cause a Top Secret binary file to be "dumped" onto that physical path, then probability indicates that 2/256 of the data will pass through as bit patterns that match the ACK and NAK characters (and of course all mismatches are flagged and can result in discontinuing the data flow).

As the number of characters allowable increases to facilitate sending other responses, which we will call control data information, the number of "hits" will increase proportionately. If we allow ten such allowable control data characters to indicate such things as "I received your request to start of job", "your job start request cannot be honored", or the like, then 10/256ths of the

possible bit patterns will pass through unscathed until transmission halt is accomplished. If 2/256 is an acceptable ratio then what must be done is to examine a string of bits wide enough to allow us to maintain the 2/256 ratio for a greater number of allowable responses. This would require at least 1280 possible patterns and could be handled with an eleven-bit field ($2^{11} = 2048 > 1280$). For the sake of convenience a field that is 2 ASCII characters wide might be a more useful width (14 bits for 7-bit ASCII code and 16 bits for 8-bit ASCII code). This would allow us to make use of standard chips for shifting and examination.

SUMMARY/CONCLUSION

A simple screening device can be used to filter control information only. This device can also detect and terminate the entire flow of data when other than the specifically delimited control information is put on the path, thereby preventing even a percentage of data from passing.

We conclude that a one-way, control-information-only data path can be used to provide the functionality required without adding a security vulnerability to this environment.

RELATED REQUIREMENTS

This Trade Study is releated to the following requirements:

100 - Special Activities - All
200 - Command Control Systems - All
300 - Emergency War Order Support - All
500 - Space Environment Support - All

RELATED SPECIFICATIONS

A20-1 through A20-3, A214-1, A226-1, A241-4, A251-1, A252-1 (e), A291-4, A292-1, A293-1, A821-3, A821-4

TRADEOFF TITLE

A22-1 How do you effect one-way communication?

REQUIREMENTS/BACKGROUND

In the configuration proposed by SDC it is desirable to have a "one-way" connection between the two secure environments. In particular, it is desired that this connection provide a data path in the direction from the low security level system to the high-level system. This is in accordance with the security principle that forbids a high security level user or process from passing data to a lower level user or process. For practical reasons, it is also desirable that some sort of acknowledgement of message acceptance (or nonacceptance) be given to the message sender. Technically, this return acknowledgement is in fact an information path that would be illegal according to the security principle just mentioned.

DESIGN APPROACHES/CHARACTERISTICS

If we are not concerned about the malicious user, or cooperating with malicious users, we can limit the bandwidth of this path in such a way that we have some reasonable assurance that "data" are not flowing through this path illegally. For example, if our connection is made up of a standard RS232 line, a typical sequence might be that: a) A sends a message to B, and b) B sends back an ACK or NAK response character indicating reception of the message or (possibly) an error condition on the line. Now for our purposes we want the path to be one way so we cut the receive wire at the proper point. Now A can send to B but can't receive. Unfortunately A can no longer receive the ACK or NAK characters either. So we can see that a return line of some sort must go from B to A and that the problem is one of limiting the bandwidth of the path.

ANALYSIS

One solution would be to insert a black box in the return line that will allow only certain characters to be returned. Since the physical mechanisms actually used in this type of configuration are in fact bit serial, the black box device must convert to characters (bit parallel), examine the characters, and pass on legal characters in bit serial form. A LSI chip exists, called UART (Universal Asynchronous Receiver/Transmitter), that will perform the bit serial/bit parallel function. Using these chips a black box that will provide the proper "one-way" functionality could be built for about $200.

SUMMARY/CONCLUSION

One-way communication can be effected by limiting the bandwidth of the data path and checking for valid data passage.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

- 100 - Special Activities - All
- 200 - Command and Control Systems - All
- 300 - Emergency War Order Support - All
- 500 - Space Environment Support - All

RELATED SPECIFICATIONS

A20-1, A213-1, A241-3, A291-5, A821-15, A821-21

TRADEOFF TITLE

A22-2 How will authentication be used for the "switching" of components within the data system?

REQUIREMENTS/BACKGROUND

To accommodate the network control approach there must be a technique included in the design to perform rapid switching while protecting the security integrity of the data within the components. It has been established that currently available techniques of software protection are not adequate.

DESIGN APPROACHES/CHARACTERISTICS

Two fundamental approaches exist: a) physically switching components with manual certification that switching has indeed taken place and b) authentication which involves encoding of data when they leave one component with decoding when they arrive at another. The keys for encoding are only available to components with the appropriate level.

ANALYSIS

A very simple device could be constructed that could provide what can be called "protective switching". That is, devices can be separated by encoding devices that allow communication only according to some specific set of rules. For example, these rules might be as follows:

DEVICE SECURITY LEVEL	CAN SEND TO	CAN RECEIVE FROM
TS	TS	TS, S, U
S	S, TS	S, U
U	U, S, TS	U

The rules could be implemented in a microprocessor-driven device that makes use of a chip in the following manner. The microprocessor maintains a table of keys that it uses in deciphering and enciphering data. Each message would have a tag "in the clear" indicating the level of the message. This tag would tell the receiver which key to use to decipher the message. Keys would be set up such that devices can only send with the key equal to their own level and such that devices would not have the keys for levels greater than their own. Even if a tag is sent incorrectly, a particular receiving device would not have the proper key to decipher messages sent from a higher level.

Keys could be stored on PROMS (Programmable Read Only Memories) that plug into the encoding devices themselves. To change the level of a device, a new key could be made available from network control.

The key tables for each level might look like this:

	UNCLASSIFIED	SECRET	TOP SECRET
TAG	UNC	SEC	TS
Send Key	K_u	K_s	K_{ts}
Receive TS Key	--	--	K_{ts}
Receive S Key	--	K_s	K_s
Receive U Key	K_u	K_u	K_u

Keys could be generated off-line and written into the PROMs by a general-purpose computer using suitable randomization techniques.

An alternate method of updating the keys would be to have a dedicated micro- or minicomputer to distribute the keys as required, under the direction of the network control officer. Because this computer would not be available for general programming the task of verifying the distribution of the keys is made much easier. Using this automated scheme for distribution of keys would allow for security reconfiguration in a matter of seconds. The limiting factor would be how fast the operational parts of the system can reconfigure the components.

Note that in this case encoding is being used to ensure that devices are correctly switched together, it is not being used to protect data from the system penetrator and therefore even a simple algorithm would suffice.

Data rates for proposed chips will be fast enough to handle channel rates. The speed limitations appear to be in the microprocessor that is used to drive the crypto device. However, all the microprocessor has to do is select the keys and feed the crypto chip. Because of the small processor requirements a small (4-bit), fast microprocessor could be used. The cost for such a device would probably be in the low four-figure range.

Also note that the actual physical links between the devices are still of concern. The two methods of doing this that have been proposed are with actual physical bus switcher or by using networking concepts.

In the case where we have communications lines of various levels entering the security periphery, the data could be enciphered immediately at the point the lines enter the periphery.

SUMMARY/CONCLUSION

An authentication technique involving a microprocessor-driven chip can be used to ensure that components that have the capability of being switched from one system to another are incapable of violating security rules. Keys associated with various security levels can be distributed either manually or automatically.

We conclude that encoding authentication of the switching of devices is a reasonable and practical method of ensuring that a given configuration is incapable of causing security violations due to misdelivery or misrouting of data.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

- 100 - Special Activities - All
- 200 - Command Control Systems - All
- 300 - Emergency War Order Support - All
- 500 - Space Environment Support - All

RELATED SPECIFICATIONS

A20-1, A20-2, A211-1 through 5, A22-1 through 3, A221-1 through 7, A223-1, 2, A215-1, A225-1, A221-3, A241-11, A252-1, A813-21, A821-2, 6, G40-2

TRADEOFF TITLE

A22-3 What role should authentication chips and switches have in the design?

REQUIREMENTS/BACKGROUND

To provide the functionality required, two important concepts must be met:

a. CPUs and perhaps other devices must be switchable from one system to another with a minimum amount of difficulty.

b. The security level of processing systems must be changeable at the discretion of the proper authority.

DESIGN APPROACHES/CHARACTERISTICS

Switching can be accomplished either via hardware or software mechanisms. Hardware switching would involve the development of a switching device or bus with automatic control to meet timing requirements. This might involve a very substantial and expensive engineering effort if difficulties existed in bringing up a connection. We believe that the alternative approach of providing software switching is more feasible but we cannot depend on software as a solution to the separation/authentication problem.

In either case the switching must be verifiable. Handshaking for authentication is one possibility or the embedding of recognizable data to ensure that security rules cannot be violated effective and inexpensive ways to provide a measure of confidence in the validity of the system configuration. Some devices are not "smart" however (such as controllers) and cannot handle a complex logic requirement. Extensive hardware modification is expensive. Encoding the whole stream as an authentication approach seems more reasonable.

ANALYSIS

Techniques and concepts for switching computer system components are developing most rapidly in the area of computer networking. Sufficient work in this area has been done to show that by using "front-end" devices and message switching techniques, devices can be effectively coupled to provide the dynamic functionality required for this application.

We have also done considerable checking in the area of the effective use of cryptographic and encoding chips. We have found that an encoding/decoding chip device can be built inexpensively (less than $10,000) which will provide positive ensurance that security rules are not violated. When used in combination with visable features, the data interface is clear or simply even in the event of misrouting.

SUMMARY/CONCLUSIONS

CPUs and other devices can be switched either physically or under some software control. In either case the "switched" systems must be verified extensively.

We can conclude that software switching using networking concepts augmented with authentication coding will provide the security and operational functionality required.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

100 - Special Activities - All
200 - Command Control Systems - All
300 - Emergency War Order Support - All
500 - Space Environment Support - All

RELATED SPECIFICATIONS

A20-1, 2, A211-1 through 5, A22-1 through 3, A221-1 through 7, A223-1, 2, A215-1, A225-1, A221-3, A241-11, A252-1, A813-21, A821-4, 6, G40-2

TRADEOFF TITLE

A24-1 Should the master data base processor transfer data to the requesting processor or directly to disk?

REQUIREMENTS/BACKGROUND

The AFGWC Master Data Base is to be centrally located as a set of files in auxiliary storage (e.g., disks) which are accessible only by the processor executing the data base maintenance programs. Copies of portions of the data base will be made and transferred on request to processors on which jobs are being set up that require the data.

DESIGN APPROACHES/CHARACTERISTICS

In providing extracts from the Master Data Base to processors which request them, the urgency of the request and the timeliness of the data are both important factors to be considered. The method to be employed in transferring the data is determined by these factors: the volume of data requested, accessibility of the destination medium, and security constraints. It is characteristic of AFGWC programs that the fields of the data base which are needed by each program are known in advance. We assume that it is generally possible to schedule a job sufficiently in advance to have the required data extracted from the Master Data Base and placed in an accessible location for use by the program prior to its execution.

ANALYSIS

If data are to be sent to the requesting processor it is necessary to synchronize the activities of the data base processor and the requesting processor. Either the data base processor must retain the data in its main memory until the job which requires it is activated, or the requesting processor must provide buffer space in its main memory to receive and retain the data until the job is activated, or the data are not extracted from the data base until the job is activated. The last option should be excluded when it is inconsistent with the goal of providing all necessary data in advance of a job in order to avoid delays in extracting from the Master Data Base. The second alternative is not

always desirable, since it ties up resource of the requesting processor (main memory) for storage of data which cannot be referenced until the relevant job starts. The first alternative is advantageous from the point of view of the requesting processor, but includes two undesirable attributes insofar as the data base processor is concerned: (1) considerable main memory may be tied up with waiting portions of data bases (even to the point of saturating the main memory capacity of the data base processor), and (2) block data transfer between main memories occurs at the maximum rate of the slower of the two memory units, which is expected to be sufficiently high as to preclude other simultaneous I/O operations. Furthermore, the direct interface between processors for synchronization and data transfer may present significant problems if the status of the receiving processor is not known.

If requested data are buffered to a shared auxiliary storage unit (e.g., disk), the difficulties associated with the approaches discussed above are avoided. Synchronization is not required, and the highly-valued main memory is not tied up unnecessarily. An additional benefit derives from the fact that the processor which requests the data and the processor which ultimately performs the job that requires it need not be the same. This permits a centralized job scheduler and network controller to direct the data base management program to extract portions of the Master Data Base for delivery to a disk at the appropriate classification level for subsequent use by a job; the job will be assigned to a processor which is cleared for the security level and which is able to access the disk through the configuration existent at that stage.

SUMMARY/CONCLUSIONS

The master data base processor should have the capability to transfer requested data to both localized disk and directly to processors for use by application programs.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A20-2, A20-3, A20-7, A215-1, A223-1

TRADEOFF TITLE

A24-2 How do we deal with incompatible interfaces and what will be the associated costs?

REQUIREMENTS/BACKGROUND

The 1975-1982 GWC data processing system will be a "mixed system configuration" i.e., a configuration consisting of both standard and non-standard computers and peripheral equipment. Being a "mixed system configuration", problems with equipment compatibility and interfacing can be expected.

Compatibility between computers and peripherals requires attention to both hardware and software differences. Hardware differences may involve speed, code, timing, word length, logic state definition, and driver and receiver characteristics. One of the most important hardware considerations is the speed of operation between units. Major differences in operational speed requires a buffering interface. For software compatibility all interconnected units must interpret the same bit sequence in the same way and the form of bit transmission, serial or parallel, if not compatible must be made so by an interface.

An additional consideration for incompatible data processing devices are the control signals that synchronize and control the flow of data. These signals may be on single or parallel lines operated as simplex or duplex transmission paths and may be multiplexed. For logic compatibility, control signals and the timing of these signals between interconnected units must be understood and taken into account.

DESIGN APPROACHES/CHARACTERISTICS

For analysis purposes, an incompatible interface is defined as an interface between equipment for which no interfacing responsibility has been established for the supplier of the equipment. The design approach to solving incompatible data system interfaces will be as follows:

a. Maximize the equipment procured from a given manufacturer to minimize incompatible interfaces.

b. Utilize applicable special computer-oriented interface modules to avoid the construction of tailored interface hardware.

c. Utilize mini computers for complex incompatible interfaces.

ANALYSIS

Specific incompatible interfaces can only be defined from a detailed design of a finalized system configuration. The technical tradeoffs that will be required for this detailed design will be dependent on the specific characteristics of hardware units to be interfaced.

The current availability of a wide variety of interface modules from data processing equipment suppliers and the development of mini computers has made it much easier to solve data transfer and routing incompatible with off-the-shelf hardware. A review of current trade literature indicates that following a detailed design of the AFGWC system the resolution of incompatible interfaces will not be a serious problem.

A possible example of an incompatible interface is between the proposed dedicated small (16 bit) mini computer for the Automated Work Centers and the Univac system processors. In all probability an interface module incorporating address selection, interrupt control, data reformatting and impedance matching will be required.

SUMMARY/CONCLUSIONS

a. Specific incompatible interfaces for the AFGWC system configuration can only be defined for a unique final configuration with specific hardware characteristics.

b. A wide variety of interface module hardware is available as off-the-shelf hardware.

c. The use of mini computers to meet data processing interface incompatibilities is now a developed and accepted technique.

d. The cost of interface modules or mini computers required to overcome operational differences between two devices is expected to range from $8,000 to $15,000 for most GWC incompatible interfaces.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

601 - General - Growth

RELATED SPECIFICATIONS

A27-1, 2

TRADEOFF TITLE

A24-3 Should mini-computers be used for complex incompatible component interfaces?

REQUIREMENTS/BACKGROUND

The future AFGWC system will, like the current system, necessarily include a variety of components which must communicate with each other for data transfer and control. A significant portion of the system design effort must be devoted to specification of active interfaces between components to overcome incompatibility.

DESIGN APPROACHES/CHARACTERISTICS

A significant development of standardized interfaces has been occurring over the last several years in the computer industry. This has been concentrated principally on providing off-the-shelf hardware modules for interfacing system components with computers, especially mini computers. These modules can be selected and tailored (often using microprogramming) to provide compatibility in speed, code, timing, word length, logic state definition, and driver and receiver characteristics. It is more cost effective to employ such readily available devices than to construct special interfaces for each of the intercommunication paths of the AFGWC system.

ANALYSIS

Interfaces within the AFGWC system which involve a computer on one or both sides (or a computer data bus) can either be supplied by the computer vendor - if the component on the other side of the interface is manufactured by the same vendor - or be developed from standardized interface modules. This is not true of interfaces between two non-computer components of different manufacture. To deal effectively with this latter situation, a mini-computer should be interjected in the path, in order that the standard interface modules might be used.

SUMMARY/CONCLUSION

Mini-computers should be used for complex incompatible interfaces.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A27-1, 2

TRADEOFF TITLE

A29-1 Should there be a total system protocol for devices?

REQUIREMENT/BACKGROUND

Total system protocol for data transfer and routing consists of the standards and conventions defined for the operational use of the hardware units within the system.

For all large systems, software or hardware, the establishment and implementation of standards and conventions is an ongoing process refined throughout the life of the system.

The design decisions formulated in the task 2 effort in respect to total system protocol are not intended to be final or all inclusive but are intended to identify those areas of profitable standardization and good practice which can serve as a base for uniform design.

DESIGN APPROACHES/CHARACTERISTICS

a. All data transfer and routing within the GWC data processing center will be performed via specific operational standards and conventions.

b. All data transfer and routing operations shall identify the security level of the data involved and the data transfer and routing shall be made in a manner that makes physical violation of its security level impossible.

c. All automatic switching and routing devices shall have an available manual backup.

d. After a data base defined number of unsuccessful attempts to transfer data, a network control function modification shall be generated.

e. Ready-to-receive and data-received messages shall be phased and routed in a manner that prevents degrading of any data transferred.

f. Data transfers shall follow specific procedures established to prevent loss of data.

g. System data routing shall be optimized in respect to the number of users of the data in order to reduce redundant operations.

h. All processors shall have a capability to output data to a spooled buffer for printer output.

i. Explicitly-defined standards will be followed in data transfer and routing messages.

j. Entry to any data to be transferred or routed must be via authorized control procedures.

k. A priority procedure for both critical and non-critical operations will exist in the network control system.

l. The primary criterion for grouping data shall be frequency of use of the established specialized data bases.

ANALYSIS

A conceptual analysis of total system protocol for devices can only be performed as a task to define the operational standards and conventions for the finalized AFGWC system configuration.

SUMMARY/CONCLUSIONS

Operational standards and conventions must be defined and implemented to insure meeting the proposed AFGWC system design specifications.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A291-1 through 7

TRADEOFF TITLE

A29-2 What should be established for satellite data reception, processing and output protocol?

REQUIREMENTS/BACKGROUND

Satellite weather data images will be generated by the AFGWC data processing system on both a scheduled and a special request basis and delivered to SID users. To facilitate the reception, processing and output product generation of SID products, an operational protocol is required which will be compatible with the overall operational schedules and capabilities of the AFGWC system.

DESIGN APPROACHES/CHARACTERISTICS

The design approach to the reception, processing and product generation of satellite weather data is to provide a system which can be initialized by a single operator input that will execute all required functions. These functions will be performed by the systems processors following preprocessing by a mini-computer and will be made available to a Satellite Data Subsystem mini-computer for both scheduled and special request products.

ANALYSIS

The initialization of the AFGWC data processing system to acquire and process satellite data will be a single input request from a system operation which will be exercised following voice communications of data arrival time from primary satellite data readout sites. All incoming satellite data will be preprocessed by a satellite preprocessor mini-computer followed by predefined processing and storage in the satellite data base. The satellite preprocessing mini-computer will provide an end-of-data ingestion message to the satellite data processor which will terminate operations through the network control system.

The SID's mini-computer will interface with the network scheduling system to request both normally scheduled and special SID products. These products will be produced by an assigned processor and held in temporary mass storage until output to the user.

SUMMARY/CONCLUSION

The architecture will assume the existence of a processing ground station for each of the Satellite data inputs: DMSP, TIROS-N, GOES and Foreign GOES. (The use of a single console or tape recording device will be transparent to the architecture.)

The functions of photo data hardcopy output and AGE image processing will be accommodated elsewhere within the system (via CRT hardcopy and high resolution data processing respectively).

The capability will exist to filter satellite data based on data base specified criteria relating to time on geographic criteria (e.g., land mass) representing the culmination of current processing requirements.

The SID interface will be automated via a minicomputer with a backup/optional standard tape drive interface.

The SID interface will accept gridded imagery produced by the vehicle dedicated interface subsystem (Site III, DUS) or via computer reconstituted imagery.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

100 - Special Activities - All

208 - Command Control Systems - TAC

300 - Emergency War Order Support - All

406 - Environmental Support - Satellite Imagery Dissemination

408 - Environmental Support - Interactive Processing and Display System

RELATED SPECIFICATIONS

A291-1, 3, 4, A292-3, A294-1, 2, A452-2, 3, 4, A461-1

3.0 COMPUTATION AND SOFTWARE

TRADEOFF TITLE

A30-1 What is the tradeoff between heterogeneous system and software costs?

REQUIREMENTS/BACKGROUND

When two or more different types of computers are to be combined in a data processing system, the effects upon software development and maintenance should be examined from several aspects. The most obvious problem is in the area of intercomputer communication. However, there are several, potentially more significant, problem areas to be considered. For example, two or more command or control languages must be employed to submit programs to the computers and invoke utility and compilation functions, and debugging programs on each computer requires knowledge of the internal work structure and instructions.

DESIGN APPROACHES/CHARACTERISTICS

(see ANALYSIS)

ANALYSIS

For each function to be programmed by GWC, a decision must be made as to which computer or computers is to perform the function. If more than one type of computer must be able to handle the function, a further decision must be made as to whether it can be programmed in a common subset of a higher level programming language, which would permit its compilation for the pertinent computers if it must be encoded two or more times for the computers. (The former method should be considered as good programming practice by GWC in any case, since the life expectancy of the GWC software may well span more than one evolutionary stage in hardware.) Regardless of the outcome of this decision process, programmers who code a function for a computer must be familiar with the form of data representation in the computer, the command or

control language required to compile and run programs, and the diagnostic and debugging tools and reports associated with the computer. They must also be prepared to deal with the instruction set and word structure of the computer if they are to use memory dumps, tracing, and patching techniques.

Intercomputer communication and data representation among differing computers may present major problems in software development. Even for interfaces among computers produced by the same vendor, there may be inadequate software for control communication, and GWC would necessarily assume full responsibility for development of interfaces for control and data transfer between computers produced by different vendors. Unless data representation is virtually identical in all of the interconnected computers, decisions will be required regarding the methods to be used in representing stored data, and data for processing or intercomputer transfer, and in determining how data bases are to be accessed (i.e., will they be directly accessible by dissimilar computers, or must one type of computer manage data bases and convert data formats and representations for transfer from and to other computers?). Factors to be considered in data representation include:

- word size,
- floating point (precision, exponent/mantissa format),
- sign (1's complement, 2's complement, sign field),
- character (ASCII, BCD, EBCDIC), and
- numbers (binary, hexadecimal, decimal).

Finally, operating systems and utility packages which are vendor supplied generally require tailoring to the installation configuration and continuing maintenance to ensure parity with subsequent operating system releases. If more than one type of computer is incorporated in the system, this effort is further complicated.

SUMMARY/CONCLUSION

None of the questions raised in the above discussion can be answered at this stage of system design. However, they must be kept in mind during the analysis

and selection process for components of the GWC system, as the factors discussed will greatly affect the cost and effort of programming the system.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

600 - General - All

RELATED SPECIFICATIONS

A311-1 through 7, A312-1 through A312-39, A313-1 through A313-4, A313-8, 12, 13

TRADEOFF TITLE

A30-2 What is the cost of interfacing systems from two vendors?

REQUIREMENTS/BACKGROUND

The nature of the configuration suggested by this study and the hardware procurement practices to be followed suggest the possibility of a final system with hardware from mixed sources (i.e. vendors).

There may be some significant additional costs involved in interfacing the different types of hardware which must be investigated.

DESIGN APPROACHES/CHARACTERISTICS

Hardware interface design costs were considered only implicitly. That is, no attempt was made to calculate these costs due to the complexity of possible combinations of vendors. Rather, the costs of hardware were rounded up, and in the case of multiple possible vendors, the maximum cost was used rather than an average cost. This approach is quite conservative, considering that the total data system hardware cost totaled tens of millions, and interfacing costs around tens of thousands for each case.

ANALYSIS

Some idea of interfacing costs can be had from the following table of vendor estimates:

VENDOR	TYPE OF UNIT	COST
Floating Point Systems, Inc.	Array Processor	\$ 6,000 - \$10,000/unit
Datawest Corporation	Array Processor	\$15,000 - one-time engineering \$ 7,000 - \$ 8,000/unit

Estimates are for attaching array processors to Univac 1100 channels.

SUMMARY/CONCLUSION

It is felt that initial hardware costs outweigh interfacing costs to such an extent that the latter can be considered as implicit in the initial purchase cost.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

600 - General - All

RELATED SPECIFICATIONS

None

TRADEOFF TITLE

A30-3 What is the breakdown of an average GWC function into wait, transfer, and compute time for the different computer sizes?

REQUIREMENTS/BACKGROUND

The wall time of an average function run on GWC facilities has been estimated to consist of the following components:

wait time	39.0%	
transfer time	27.3%	overlap between transfer and compute = 13.4%
compute time	47.1%	

These numbers are based on functions running on a UNIVAC 1108 processor. To determine the number of large processors required to meet GWC requirements, these new wait/transfer/compute/overlap times must be examined.

DESIGN APPROACHES/CHARACTERISTICS

(see Analysis)

ANALYSIS

Decision:

computer	MIP	compute %	transfer %	overlap %	wait %
1108	.75	47.1	27.3	13.4	39
1110 (1x1)	1.4	54	28[2]	20[3]	40[4]
1100/40	2.6	35[1]	35[2]	20[3]	50[4]
CYBER 175	6.2	17[1]	41[2]	17[3]	59[4]
IBM 370/195	12.5	8.5[1]	41[2]	8.5[5]	59[4]

(Superscripts defined on next page.)

Superscripts:

1. Determined by applying faster MIP rate.
2. Assume transfer rate increase by factor of 2 due to faster disk (8440 vs 8433), and the effect of using more main memory which will result in more data being kept in core, hence fewer disk accesses.
3. Assume ideal maximum overlap of 20% of wall time.
4. Assume that all of wait time was due to disk and this has decreased by factor of 2, due to the use of disks with smaller rotational delays and due to more paths to a given disk (multiple control units).
5. When compute drops below 20%, assume all compute is overlapped with transfer.

SUMMARY CONCLUSION

In general, machines which can compute faster will begin to be limited by their transfer rates. This means that for an "average" GWC function all compute time will eventually be overlapped with transfer time and this limiting case will then break wall time down to 41% transfer and 59% wait.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

600 - General - All

RELATED SPECIFICATIONS

None

TRADEOFF TITLE

A30-4 What is the tradeoff between retaining RTOS along with required upgrades and starting from scratch?

REQUIREMENTS BACKGROUND

RTOS (Real Time Operating System) is a very large routine written entirely in assembly language. As the functions which RTOS must accomplish evolve and new hardware is acquired, upgrades become extremely complicated and costly.

DESIGN APPROACHES/CHARACTERISTICS

(see ANALYSIS)

ANALYSIS

This question has to be postponed until more is known about the ultimate configuration. If the computer hardware with which RTOS must interface is other than UNIVAC, an entire rewrite from scratch will probably be necessary due to language and structure incompatibilities. Even if the present relationship with UNIVAC is retained it will most likely not be able to react to necessary change smoothly and efficiently.

SUMMARY/CONCLUSION

Upgrading versus completely rewriting RTOS must be left as an option.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

200 - Command Control Systems - All
300 - Emergency War Order Support - All
500 - Space Environment Support - All
409 - Environmental Support - Operations Security
416 - Environmental Support - Backup to Carswell

RELATED SPECIFICATIONS

A343-1

TRADEOFF TITLE

A30-5 What is the minimum number of a single size of computer required to meet GWC's needs?

REQUIREMENTS/BACKGROUND

This study is essentially a continuation of A30-3 which breaks down the expected wall time of an average GWC function for the different computer sizes. Once the makeup of the wall time is understood, we can determine the number of processors required to handle the expected load of functions.

DESIGN APPROACHES/CHARACTERISTICS

This estimate will not take into account security and reliability since these depend on an overall configuration. The numbers which follow attempt to judge the number of processors needed to independently accomplish the models' remaining requirements.

ANALYSIS

Results of Study:

number of processors required

computer	RP	nominal load: other requirements	nominal load: models	peak load: other requirements	peak load: models
1108	1	6	--	14	--
1110 (1x1)	1.8	4	--	8	--
1100/40	3.5	2	--	4	--
CYBER 175	6.3	1	--	2	--
IBM 370/195 or					
	13.5	1	4	1	5
PROTEUS	50	--	3	--	3
	60	--	3	--	3
	95	--	2	--	2

(the dashes indicate the computer has no application for the given requirements).

The numbers for "other requirements" have been derived from "average" statistics for function wall time determined in A30-3 for five different computer rates. (The final three are ignored since they are special-purpose computers which do not allow simultaneous executions.) From these have been calculated the number of average functions which would be able to be acted on concurrently. The next step was to establish the relative wall times of the functions running on the different systems by again evaluating the statistics computed in A30-3. With these two sets of figures the number of functions completed per unit time can be easily determined:

computer	RP	simultaneous functions	wall time	function per unit time
1108	1	2.19	1.00	2.19
1110 (1x1)	1.8	1.92	.486	3.95
1110/40 (2x1)	3.5	2.86	.399	7.37
CYBER 175	6.3	5.88	.341	17.5
IBM 370/195 or CYBER 76	12.5	12.5	.341	35.3

The network analysis has shown that in the nominal case at most 12 programs other than the primary models will be active simultaneously and in the peak case a maximum of 29 "other programs" will be active concurrently. Using the figures for "number of functions completed per unit time" with these statistics and rounding the resultant processor estimates upward we are left with the processor requirements expressed at the beginning of this ANALYSIS.

For the primary analysis and forecasting models the nominal and peak numbers of 4 and 5 are used. Since the first four computer sizes cannot accomplish these models in the necessary time span no estimate of needed processors is made. Furthermore, since the major models are not yet in existence, only an estimate of needed resources can be made. For these purposes, estimated CPU time has been used which leads to the assumption that each active model requires an additional processor. As the computer speed increases, the models will be finishing faster causing less simultaneous executes and therefore requiring fewer processors. In short, this determination has been approximate.

SUMMARY/CONCLUSION

To determine the minimum number of a single size of computer required to meet GWC's needs, we have broken down functional requirements into two classes: 1) those that can be classed as models, and 2) all the rest. Each of these classes has then been evaluated separately since they demand different computer resources. The evaluation from this point is then straightforward, resulting in the numbers shown in the "Analysis."

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A311-1, 2, 4, A312-1, 6, 38, 39, A121-1 through 3, A123-1 through 11

TRADEOFF TITLE

A30-6 Based on an assumed configuration mix, determine the number of processors required to meet the GWC workload by including the factors of security and reliability.

REQUIREMENTS/BACKGROUND

The number of processor alternatives for this tradeoff study was narrowed down to the five described by consideration of the following factors:

a. The economics of scale achieved in general-purpose processors; also CPUs come in certain fixed sizes, with vendors supplying competing machines of comparable power (see Table 3.1).

b. Division of GWC processing into a general mix of small jobs and a small set of numerical models,

c. The cost of software conversion in departing from UNIVAC and the desirability of staying with the mainstream of the data processing community, and

d. Homogeneity of processors being the least cost approach due to single operating system and simple hardware maintenance; the simplifications of network scheduling; and interchangeability of software among machines with identical characteristics.

The economics of scale and the vendor pricing policies create an effect known as "Grosch's Law" (see Table 3.2) i.e., the price goes up in proportion to the square root of the processing power. Therefore, it is advisable to choose the minimum number of the largest CPUs available to the extent that a sufficient number of processors exist to deal with the conflict problems. This results in alternative B (see Analysis Table 10.11) or 8 12 RP machines. Consideration of factors 2 and 3 result in alternative A, a mixture of 3.5 RP and 12 RP machines. UNIVAC can supply machines in the 3.5 class (1100/40 2x1 or 2x2) but not in the 12 RP class.

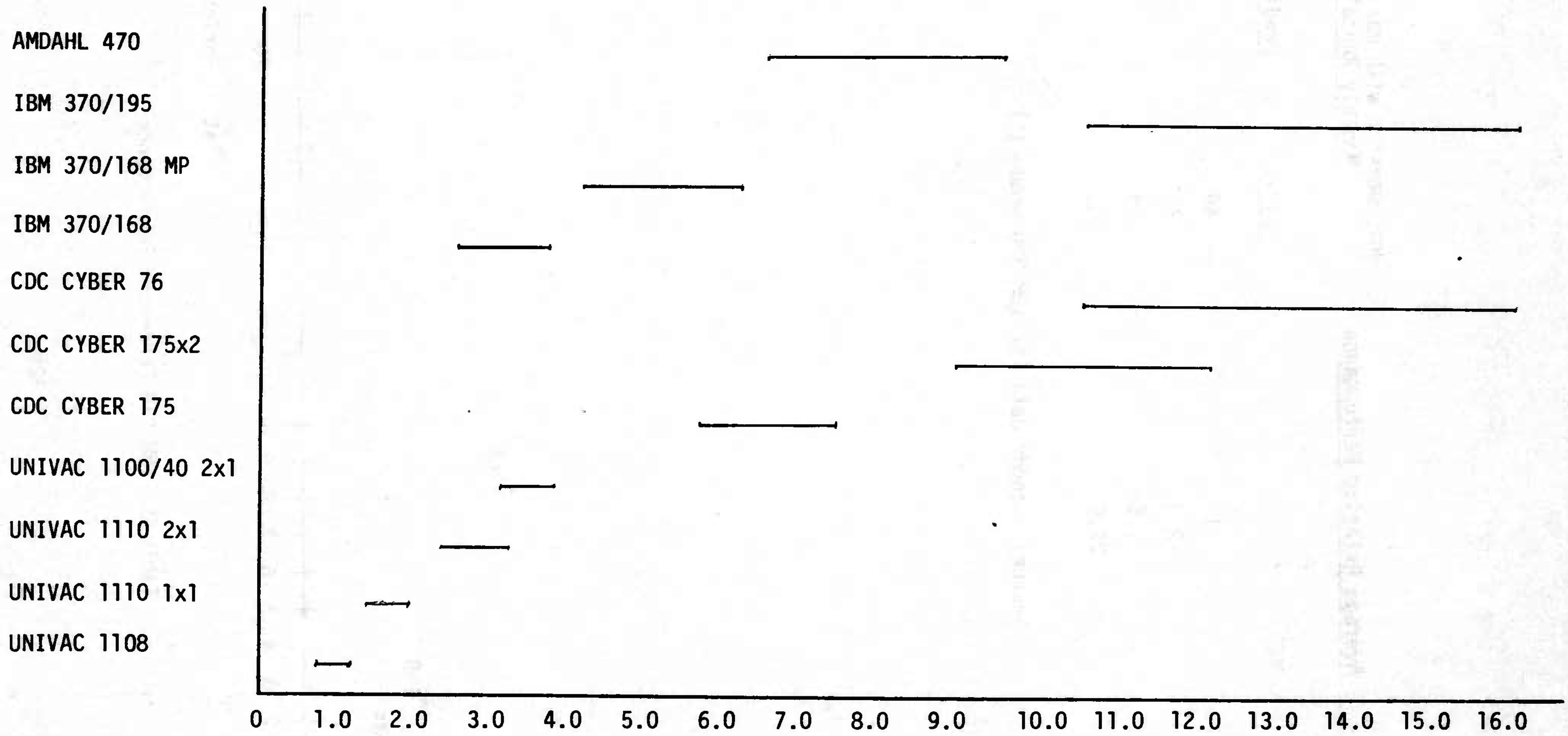

Table 2. Processor Relative Performance

Model	Average Relative Performance	Uniprocessor with maximum main memory Monthly Rental ($000) Actual	Predicted ($\sqrt{RP} * 40$)
350/145	1	40	40
370/158	2.3	62	61
370/168	7.6	110	110
370/195	22.6	186	190

Source: vendor data for IBM 370 product line.

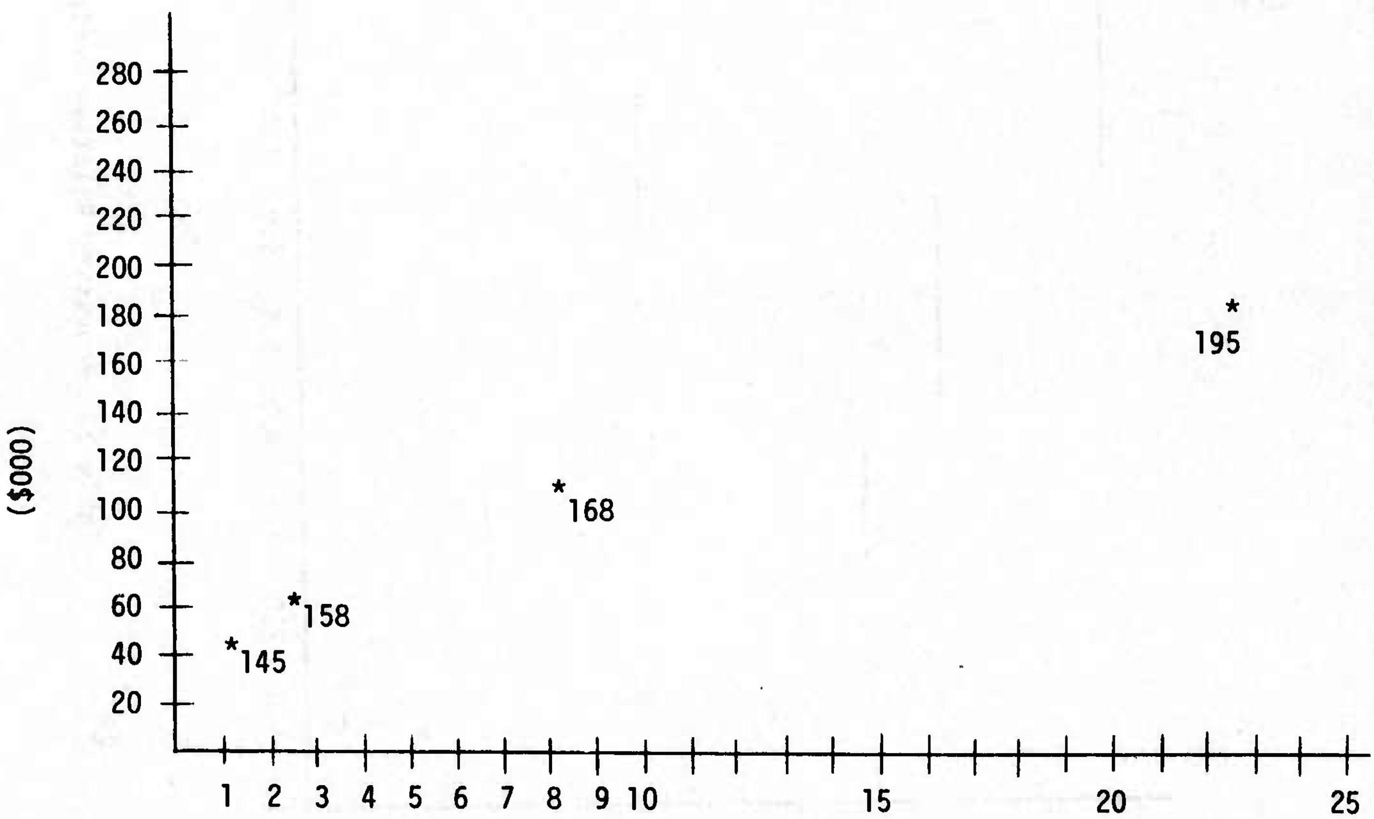

Table 3. IBM 370 Processor Performance

These (1100/40 2x2) can be partitioned by Network Control into uniprocessors, dual multiprocessors (or even 4x4 multiprocessors if they are properly configured) depending on the security and processing constraints of the moment. They were not described as 4x4 s instead of two 2x2 s for several reasons:

1. It is very difficult to rank the processing power of a 4x4 due to the lack of actual performance data. Since a 4x4 has the same maximum memory as a 2x2, it may be difficult to keep enough functions in memory so that the two additional CAUs can be utilized. In addition, the memory conflict will rise nonlinearly with the number of CAUs. These factors indicate that a 4x4 configuration is warranted only under special circumstances.

2. None of the projected functions requires more than a 2x2, other than the models, and they will be run on 12 RP or faster machines.

3. There was an odd number (five) of these machines required, so we could not have identical processors if they were grouped as 4x4s. (It would be very unlikely that physical proximity requirements could be satisfied for using the 2x2 in the variable perimeter to make up a 4x4 in SX <u>and</u> in normal access.)

4. Security constraints are likely to cause the system to normally be split into smaller units than 4x4s

Because UNIVAC can supply processors of the 3.5RP class, the software conversion cost could be zero for this option, offsetting the hardware price advantage of the 12RP class machines. Furthermore, the 12 RP machines are not in the mainstream of vendor interests. They therefore have the drawbacks associated with owning a machine that is not owned by very many other people. For example, the IBM 195 does not run the current operating system, VS, and IBM will not enhance OS any further. Therefore, the 195 customer cannot take advantage of the technological progress and supporting being given VS users.

By using a 3.5-scale machine and an array processor, GWC will be able to take advantage of continuing vendor support and a large community of users of similar equipment. SDC does not intend that UNIVAC 1100/40s be equated with the 3.5 RP machines. The decision still remains as to whether to go competitive or not.

If UNIVAC wins the data base procurement then based on software conversion costs there may be a strong argument to procure solesource. Only the Air Force can consider the legal aspects of this decision and can quantify in terms of cost the advantages and disadvantages of a sole source procurement and weigh the balance against software cost savings. For example, the IBM 370/168, AMDAHL 470, and CDC CYBER 175* are also capable of providing comparable performance. SDC is only suggesting that alternative B be retained instead of A for the reasons previously stated.

The homogeneity of processors means that they are all from the same vendor, have identical features including memory, and can, therefore, be considered interchangeable. This minimizes the cost of maintenance and simplifies network scheduling. It also minimizes the cost of redundancy. When the system was split into two categories (3.5RP and others), we therefore assumed identical processors within each category.

The Task 1 analysis indicated that five models could be in conflict at one time. These models were estimated to require a significant portion of a dedicated 12 RP class machine. One such machine must also be available for backup and preventive maintenance. Hence, six such machines would be required by 1982. Alternately, it should be possible to augment the CPU power of a general purpose machine with an array processor or a parallel processor. Because of the very fast logic and/or parallel computation of these machines, we should never need more than two plus a backup (options C&E).

For machines of the 60 RP class, the requirements dictated two plus backup units. These machines are generally used in an R&D environment and do not have high reliability. Their cost is also quite high, but they were included due to GWC interest (option D).

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*Performance rankings for the AMDAHL 470 and CYBER 175 are based on vendor engineering estimates, rather than benchmarks. They are considered by SDC to represent at least 3.5 RP machines.

DESIGN APPROACHES/CHARACTERISTICS

Once the kinds of processors involved in the various configurations have been determined, it remains only to determine the number of the various processors needed. This is the route taken in the analysis of this problem.

ANALYSIS

Results of Analysis on five Alternatives:

a.	3.5	RP	(UNIVAC 1100/40)	5
	60	RP	(ASC)	5
			(STAR)	6
b.	12	RP	(195 or CYBER 76)	8
c.	3.5	RP	(UNIVAC 1100/40)	5
	12	RP	(195 or CYBER 76)	6
d.	3.5	RP	(UNIVAC 1100/40)	5
	50	RP	(any array)	4
e.	95	RP	(STARAN or PEPE)	3

These figures are based on the following assumptions:

1. The estimates made in 30-5 will fulfill the GWC requirements providing reliability and security are neglected;
2. If at least five processors of a given type are available, then no additional computers are required for security reasons (the security problem is being considered minimal where the models are concerned);
3. A minimum reliability of .995 is the goal.

The specific data which have gone into making the "decision" follows:

	Computer	Size	Individual Reliability	Processors Needed for: Production	Reliability	Total
d	1100/40 ASC/Star	3.5 60	.999 .931/.7	5(.005) 3(.193)	0 0	5(.005) (.002)
a	CYBER 76 or 195	12	.988	7(0.81)	1	516(.002/.071) 7(.004)
b	1100/40 CYBER 76 or 195	3.5 12	.999 .988	5(.005) 5(0.59)	0 1	5(.005) 6(.002)
c	1100/40 array	3.5 50	.999 .998	5(.005) 3(.006)	0 0	5(.005) 3(.006)
e	1100/40 STARAN or pepe	3.5 95	.999 .996	5(.005) 2(.008)	0 1	5(.005) 3(.001)

The numbers in parentheses indicate the probability of failure (1-reliability) for that number and type of processor.

SUMMARY/CONCLUSION

Security has not proved to be a factor in this analysis given the relatively large number of processors required to accomplish functions. Other than the functions themselves the most important point affecting the outcome of this analysis has been the reliability goal of .995.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A311-1, 2, 4, A312-1, 6, 38, 39, A121-1 through 3, A123-1 through 11

TRADEOFF TITLE

A30-7 What is the distribution of processing according to the highest classification absolutely required?

REQUIREMENTS/BACKGROUND

In order to understand the total effect of security problems on a configuration proposed for GWC, it is necessary to understand the relative distribution of classification levels among the various functions.

DESIGN APPROACHES/CHARACTERISTICS

The approach taken in this evaluation was to break down all GWC functions into the four main areas defined in Task 1: input data processing, data base and related computations, output processing, and software processing. Within these four principal regions the breakdown was then carried on to the type of product a computation involved. Finally at this point it became possible to estimate the percentage of wall time involved in the various classifications. For our purposes here, only four security levels were considered: Unclassified, Confidential, Secret, and Top Secret.

ANALYSIS

Results of Study

Unclassified	95%
Confidential	<1%
Secret	<1%
Top Secret	4%

The security mix indicated above is based on percentages of wall time spent in different classification levels. Those figures are based on the following breakdown of functional areas:

- input data processing -				
space environmental data	87%U	3%C	4%S	6%TS
conventional data	100%U			
met sat/imagery data	100%U			
product requests	75%U	4%C	8%S	13%TS
digital radar	100%U			
special projects	25%U	75%TS		
- data base & related computations -				
SESS computations	100%U			
request processing	50%U	10%C	15%S	25%TS
analysis computations	100%U			
forecast computations	100%U			
special projects	25%U	75%TS		
- output processing -				
SESS products	87%U	3%C	4%S	6%TS
facsimile products	100%U			
satellite/imagery related	100%U			
AWN products	100%U			
special projects	25%U	75%TS		
- support processing -				
software development & maintenance	100%U			

SUMMARY/CONCLUSION

It has been shown that the majority of computer wall time is spent on Unclassified function (95%), with 4% Top Secret, and the remaining 1% Confidential and Secret.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

100 - Special Activities - All

200 - Command Control Systems - All

300 - Emergency Was Order Support - All

500 - Space Environment Support - All

RELATED SPECIFICATIONS

None

TRADEOFF TITLE

A30-8 Should we utilize a single-array processor or try to split up the problem to be accomplished on several processors?

REQUIREMENTS/BACKGROUND

This question addresses the possibility of taking a function suited for an array processor and breaking it up so that it could be solved in parallel on several conventional type processors.

DESIGN APPROACHES/CHARACTERISTICS

Utilizing the technology of tightly coupled multiprocessors, one still only gets about 85% efficiency out of two computers that can be obtained from one the same size. This is misleading of course to the extent that the parallelism afforded in side-by-side processors presents a slightly more simple network control problem. (For example, based on the time of arrival of a job you cannot necesarily get the two jobs done as early on a single processor with twice the power as you can on two processors without splitting the jobs.)

ANALYSIS

The variables in this problem seem to be in inefficiency resulting from splitting a problem up, the ability of the network control computer to efficiently schedule two or more jobs, the size and distribution of the jobs, the efficiency of the computer in terms of wait time and I/O compute overlap, the number of jobs that can actually be run on the computer (i.e., its versatility), and coordination between processors.

SUMMARY/CONCLUSION

This question comes down to a detailed evaluation of any particular function in question. It must be studied with each of the points discussed under "Analysis" examined before a decision can be made.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

601 - General - Growth

RELATED SPECIFICATIONS

None

TRADEOFF TITLE

A30-9 Should we specify special array, parallel, or associative processors for models?

REQUIREMENTS/BACKGROUND

An investigation of the nature and functions of the major AFGWC models indicates that they tend to saturate some capabilities of conventional computers without approaching full utilization of others, and that unconventional computers might be more effectively employed to operate these models. The question is, which of three general classes of computers is most appropriate, assuming that a mix of unconventional computers is undesirable.

DESIGN APPROACHES/CHARACTERISTICS

Array processors are best suited to programs which apply essentially the same algorithm to many similar sets of data, with little or no crosstalk between the data sets. However, they require a host computer to supply the array of data sets and a list of instructions for the elements of the array. Parallel processor systems can be effectively employed in two ways: to allow more than one algorithm to be applied concurrently to a single block of data when no conflicts or inconsistencies can occur; and, to perform two or more independent tasks which involve distinct data. Associative processors are best employed in situations in which the data are not well-ordered (i.e., addressable) for the algorithm being executed, and reordering is impractical or unfeasible.

ANALYSIS

All of the major AFGWC models operate on data which are prearranged according to geographical grids. Since the models perform essentially the same function for many or all points of a grid, they are most amenable to array processing. Normally, not all of the data associated with a grid are brought into main memory for execution of a model; instead, selected fields are extracted from the data base which resides in auxiliary storage, and processing is then performed with the obtained data through relatively simple construction of addresses based on the geographic grid structure. (The data base structuring

and accessing programs may lend themselves to operation on associative processors, but this is not the question being addressed.) Parallel processors could also be usefully employed in operation of models, but would not have the impact on execution time that could be achieved with array processing. Typical grids are 29x35 and larger, and, while parallel processors could substantially reduce running time in comparison with simplex processing, even small-array processors (e.g., 20x20) could greatly increase model performance. Associative processors could not be used to advantage for model operation, since the data addressing is relatively straightforward, and it is computing power that is needed.

SUMMARY/CONCLUSION

Of the three classes of unconventional computers, array processors offer the greatest potential for superior performance of model operation, and should be specified as a part of the AFGWC system for this purpose.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A121-1, A123-1 through 11, A311-2, 4, A312-1 through 39, A264-2

TRADEOFF TITLE

A30-10 What is the tradeoff between using separate processors for special functions or part of a large processor?

REQUIREMENTS/BACKGROUND

The type of operations or special functions which might be candidates for this consideration include communication, peripheral, data base, and satellite data.

DESIGN APPROACHES/CHARACTERISTICS

Factors which should be considered include:

a. homogeneity tradeoff,
b. availability of existing software support,
c. cost tradeoff (specially designed processor versus fraction of large processor), and
d. Undesirability of mixing vendors (i.e., interface problem).

ANALYSIS

The most serious argument for homogeneity is avoiding the redundancy. A simple example is that if a 10% redundancy is required to meet the reliability requirements and there are 10 computers required, then one extra is required for redundancy. If there are two different brands of computers, five of each, then two computers are required for redundancy. Homogeneity can save the 10% in cost under that circumstance. It gets even worse if you consider three or four brands of computers.

SUMMARY/CONCLUSION

As far as possible, we should avoid dedicating processors to specialized functions. It is more cost effective to dedicate part of a large computer to such a function. This conclusion does not conflict with that of A33-2. Obviously separate processors are called for to handle some special functions.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

None

TRADEOFF TITLE

A30-11 What is the tradeoff between splitting up large jobs versus more computer power?

REQUIREMENTS/BACKGROUND

The requirement challenged by this tradeoff is time: what approaches can be taken that will ensure a large function is completed in time?

DESIGN APPROACHES/CHARACTERISTICS

There are basically two opposing approaches to this problem:

a. the first involves some amount of software development and entails splitting up a large function into smaller components.

b. the second involves acquiring more computer power to ensure that the function can be completed in its large complicated state.

ANALYSIS

Splitting up large jobs usually is not difficult. Whenever you split up a program between two separate runs or two separate machines, it does involve documenting a detailed interface at the split and in the case of two different machines providing for recoupling through the data base. A further consideration is time since one may not have control over when these two portions are run with respect to one another, or in some cases not even the sequence. This is where a well-designed network control option can be of value. The actual computer power saved depends upon the number of conflicts which can be deleted by better flexibility in scheduling.

SUMMARY CONCLUSION

Whenever possible, large jobs should be split up into smaller components to meet time requirements and save computer power.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

601 - General - Growth

RELATED SPECIFICATIONS

None

TRADEOFF TITLE

A31-1 Can multiprocessors exist under the security requirements?

REQUIREMENTS/BACKGROUND

Multiprocessors run in their multiprocessing configuration must be at the same data path level. The question becomes: If they are run as multiprocessors, can they be run at different levels?

DESIGN APPROACHES/CHARACTERISTICS

(see ANALYSIS).

ANALYSIS

They can be run at different levels under the conditions that they do not reside as part of common data paths (i.e., they cannot chare the same main memory, disk memory, or channels to other components). Further, they must be physically isolated in the same sense as other components, where a switch can make them independent of one another and protect against inadvertent passage of data. The specifications for this distinction must be strict.

SUMMARY/CONCLUSION

With enough care and preplanning, multiprocessors can be run at different security levels.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

100 - Special Activities - All

200 - Command Control Systems - All

300 - Emergency War Order Support - All

500 - Space Environment Support - All

601 - General - Growth

RELATED SPECIFICATIONS

A311-2, 4, 8, A264-2 through 4

TRADEOFF TITLE

A31-2 Should data base management be accomplished on a single machine or should it be a time-shared function on several machines?

REQUIREMENTS/BACKGROUND

The job of data base management is expected to become more complicated and sophisticated in the future. It will be a major specialized function. It should be decided whether it is better to dedicate it to a particular processor or allocated it as a time-shared function on several machines.

DESIGN APPROACHES/CHARACTERISTICS

Because of the desire to minimize I/O time where computation is not simultaneously being performed, it is important to minimize data access and wait time. The problem with interjecting a separate processor is that the time is great to receive the input, perform the necessary computations, access the data and then make the communications link with the original requester. If this time delay were increased due to the interjection of the network control function which would determine which processor was to do the job and schedule it, this would be a handicap. However, the real question is the tradeoff between that operation versus the handling of multiple requests by a single computer dedicated to the function.

ANALYSIS

This is a tough decision,and the tradeoff is neither obvious nor presently provable. We strongly suspect that action on a single machine would be faster in this instance. The other consideration is the design problem of multiprocessors accessing a single data base simultaneously. We feel this would result in wait time whereas the activities of the single processor, although not necessarily faster, would be more efficient in terms of wait time.

SUMMARY/CONCLUSION

Because of the design problems we recommend that Centralized Data Base Management be dedicated to a specific processor.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A132-1 through 6, A341-3, 7

TRADEOFF TITLE

A31-3 Can we link an array processor (AP) to more than one host?

REQUIREMENTS/BACKGROUND

Array processor usage should be optimized due to the expense ($500,000 apiece). Hence, consideration should be given to the possibility of sharing array processors between hosts.

DESIGN APPROACHES/CHARACTERISTICS

Sharing an array processor (AP) between to hosts requires that the following conditions be met:

a. The hosts coordinate their usage of the AP.
b. The array processor be within cabling contraint distance of both hosts.
c. The overhead of multiplexing the AP between hosts is insignificant.
d. The number of hosts must be greater than the number of AP's required for meeting reliability and scheduling constraints.
e. In addition to the above, the AP must be sufficiently fast that several hosts are required if it is to be kept busy.

ANALYSIS

The analysis is broken into a discussion of each of the conditions listed under Design Approaches/Characteristics:

a. Coordination of two CPUs requires a shared memory where the queue of AP activities can be kept, or a high-speed connection where hosts can update tables kept on each other's memory devices. For the latter to work, one host must have precedence in its requests and this must be known to both hosts. As will be seen in the following discussion, this is the only condition that can be met with certainty at AFGWC.

b. The AP must be hung on a memory bus of the host to prevent a host to AP bottleneck. This constrains APs to be within about 12 feet of cable from the host. Hence, it is unlikely that hosts can share APs due to the very close proximity required of the hosts.

c. The APs must be flexible devices to allow the highest probability of success in meeting future (not completely defined or analyzed) requirements. Thus, they are specified as being controlled by a loadable microstore. The write time of the microstore is far slower than the read time, hence the overhead of changing routines in the AP can be very significant. Therefore the hosts that share the AP would have to be solving problems that require identical microcode in the AP. This is not likely and certainly cannot be guaranteed.

d. Each host must have its own AP to meet reliability and scheduling requirements. That is, if a processor system is taken for PM, its role must be assumed by some other processor system. Role switching may also occur due to unscheduled downtime. Thus, each processor system must be prepared to run numerical models on an AP. Since cabling constraints are tight (see b) for AP, this means that each processor system must have its own AP.

e. The APs specified by SDC are capable of autonomous operation to a great extent. They have large local memories for manipulating intermediate results. Further, they can overlap their computations with those of the host. It is unlikely, therefore, that during a numerical model, they would be waiting on the host.

SUMMARY/CONCLUSION

Each processor system should have its own dedicated AP.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

601 - General - Growth

RELATED SPECIFICATIONS

A312-1 through 3, A312-5 through 13

TRADEOFF TITLE

A31-4 Can network control and central data base management have their bullpen backup residing on the same multiprocessor as the primary function?

REQUIREMENT/BACKGROUND

Both necwork control and central data base management are functions which must have an extremely high degree of reliability and a ready backup to assume capabilities in the event of a failure. This is because the entire data system is dependent upon the control and management provided by these two functions.

DESIGN APPROACHES/CHARACTERISTICS

The bullpen backup can reside in two places. First, the backup could be on the second half of a multiprocessor (in effect we could trust the reliability of a multiprocessing system to be high enough as to approach unity). Second, we can place the bullpen backup on a separate multiprocessor system. Third, we can force the systems running network control and central data base management to be partitioned into uniprocessors.

ANALYSIS

Having central data base management and network control reside with their backup on a multiprocessor, that is trusting the multiprocessor to be absolutely reliable, is very convenient from the standpoint that it simplifies switching of peripherals and that is simplifies overall network scheduling. Moving the backup to a separate multiprocessor system complicates network scheduling because both network control and central data base management are very high priority functions. Hence, we do not want to place functions which will require high priority or real-time responses, or which are very compute-bound and must finish within a certain tight deadline, on those two processor systems unless absolutely necessary. Therefore, if we make their backup a separate system we either incur the liability that the primary may fail while the backup is running a high priority job, or we severely constrain scheduling. Also the bullpen backup is a warm backup and requires a program to be loaded and ready in memory.

Hence, the backup system does not have as much memory available to it for other functions as would be normally desirable.

Forcing a processor system to run as two separate uniprocessors has several disadvantages. First, a multiprocessor can share peripherals more efficiently. Finally, there are many errors that a multiprocessing system can recover from that uniprocessors cannot. However, most of the errors that cause processors to fail are those which would cause the multiprocessor to fail as well as the uniprocessor. To be more specific, the errors that most often cause the processing system to fail are those which are the result of software failures within the executive. In this case, the result is usually a deadlock which forces an operator to reinitialize the system. Secondly, hardware failures within a processor system are normally the result of memory failures. Such memory failures can happen to either the region in which a problem program is operating or the region in which the executive is operating. If it's the problem that fails, it could be either an unimportant program or it could be the software for central data base management. If it's in the executive region, the executive will probably not be able to recover from the failure.

SUMMARY/CONCLUSION

In summary there is no clear-cut way to go. The best option appears to be to specify an extremely high hardware and software reliability for both network control and central data base management, backed up by having the bullpen processor separate from the processing system that is running the primary function. The backup copy of the program could be kept in a roll-out status until it is required to become active. This would minimize the impact on memory of having the backup function on a separate computer.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

601 - General - Growth

RELATED SPECIFICATIONS

A341-7

TRADEOFF TITLE

A31-5 Should miniprocessors be used for tasks like printer interface, console interface, and communications interface?

REQUIREMENTS/BACKGROUND

Printer, console, and comm interface are among the type of activities which can be easily adapted to mini processors. This option should be considered as an alternative to relegating such functions to the large mainframe computers.

DESIGN APPROACHES/CHARACTERISTICS

(see ANALYSIS)

ANALYSIS

Large computers which are heavily involved in computation cannot efficiently be employed in servicing a multitude of peripheral devices which require little computation but frequent attention. Such a load imposes significant task switching overhead on the computer and temporarily deactivates processor capabilities which are not applicable to peripheral service. The relatively low cost of miniprocessors which can perform such services makes them an attractive and appropriate alternative to use of the large computers. Not only can off-loading of service functions to minicomputers provide for more effective use of large computers, it can result in better performance of the system. This results from the ability to code the miniprocessors to deal with the special requirements of individual peripherals without concern for tying up the significant resources of the large computers. Thus, functions such as device polling, blocking, and immediate response to interactive user terminals can easily be provided to the extent required. Additional functions such as text editing, calculation, and memory aids may also be provided to interactive users.

SUMMARY/CONCLUSION

There are some functions which should be dedicated to miniprocessors, specifically interface with communications lines, control of consoles and routing of control only and upgrade data.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A122-2, 3, A313-1 through 17

TRADEOFF TITLE

A31-6 Should there be several processors for communications or a single one?

REQUIREMENTS/BACKGROUND

Capacity and capability are not the principal processor requirements for communications processing. The primary factors to be considered are security constraints and reliability demands.

DESIGN APPROACHES/CHARACTERISTICS

Transmissions into and out of the AFGWC are classified as Top Secret, Secret, and Unclassified. In order to isolate the Secret and Top Secret messages and eliminate the possibility of inadvertant crosstalk which would violate security, each class of transmission should be identified and directed through a processor which is assigned exclusively to the appropriate classification level.

The reliability requirement dictates a redundant capability for communications processing which ensures no loss of critical data and minimal loss of noncritical data; i.e., at least two processors are needed, with either able to assume the entire communications processing function.

ANALYSIS

The security requirement implies at least three communications processors for meaningful isolation. Full redundancy is not required at all security levels since the planned system includes the capability for switching processors into different configurations, with automatic "cleaning" as required for downgrading between security levels. This process is estimated to require on the order of 10 to 30 seconds, and would enable one or at most two processors to back up the complement of three processors needed to meet the security demands of AFGWC communications.

SUMMARY/CONCLUSIONS

A minimum of four processors should be assigned to handle AFGWC communication functions.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A343-1, A40-1 through 10, A451-1 through 22

TRADEOFF TITLE

A32-1 What programmer support software should be provided (e.g., interactive programming language)?

REQUIREMENTS/BACKGROUND

Many software tools are available to aid the programmer in the development and maintenance of his programs. GWC's special problems require a special look at these tools.

DESIGN APPROACHES/CHARACTERISTICS

Special software which applies to a special application such as the software required to structure and access the AFGWC central data base is not considered support software for the purpose of this discussion but is classed with the applications and operating system software. Interactive text editing capabilities, interactive HOL compilers with multiple levels of compilation and analyses, and the capability to embed debugging statements which can be optionally included in the object program represent the basic set of tools required for software development in a facility which has interactive consoles for program development. The automated configuration management tools discussed below (see ANALYSIS) represent a minimum capability required to provide logistics type support for the software development programmer and control to the software development manager.

Other more sophisticated software development tools are available ranging from programs which read a FORTRAN program and make suggestions regarding testing procedures to System Simulation-Construction tools which support the transition of functionally simulated systems to real time systems with constant visibility and feedback. Based on estimates of the utilization of such tools, the cost of such tools, and the meteorologist-programmer rotation, investment in these more sophisticated, more complicated tools is not merited.

ANALYSIS

The support software capabilities listed below represent a basic set of software tools appropriate for the efficient development of applications software at the AFGWC facility by a large cross section of programmers attached to it.

Support software which should be provided at AFGWC includes:

1. An interactive text editing capability which can be used to update either program character stream or text used for documentation purposes.

2. Automated configuration management tools which provide for:

   a) Update of computer programs such that each version (mod) of a program is retained and can be retrieved until deliberate actions are taken by the file owner to purge the version.

   b) An audit trail of program modifications.

   c) Both testing and operational versions of all programs under configuration management. Changes would be allowed in testing versions. Changes would not be allowed in operational versions. Operational versions of a given program would enter the system or replace older versions only by directive of the configuration manager.

3. An interactive compilation capability where the compiler options would range from a capability for highly interactive entry of new code augmented by language primer information printouts to an option to compile an optimized version of a program.

4. A capability to embed debugging statements in a source program such that they can be optionally compiled as part of the object program or treated as comments or stripped out of program. This capability could be provided by a preprocessing program if the compiler(s) available does not provide it.

<u>SUMMARY/CONCLUSION</u>

There are specific programmer support software tools which are applicable to GWC's problems and environment.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

602 - General-Manpower Productivity

RELATED SPECIFICATIONS

A331-1 through 18, A528-1 through 12

TRADEOFF TITLE

A32-2 Should we look at higher order languages (e.g., analysis)?

REQUIREMENTS/BACKGROUND

GWC's special problems and projects may benefit from the use of higher order languages tailored to specific needs.

DESIGN APPROACHES/CHARACTERISTICS

(see ANALYSIS)

ANALYSIS

We recommend that a language translator with a macrostatement capability be considered for the evolutionary development of languages to support activities such as analysis, report generation, query/response, etc. The translator should permit development of libraries of macro definitions which can be employed by users either to accomplish a desired effect, or to construct other macros. Users should be able to design macrostatements to suit their purposes and to have the use of such macros be translated either into FORTRAN (or some other general programming language) for compilation, or into a conversational language which can be interpreted in real time.

SUMMARY/CONCLUSION

Because of the cost savings possible this should remain as a design option.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A528-10

TRADEOFF TITLE

A32-3 What is the tradeoff between dedicating a function to a processor and batched processing on several (i.e., consider system utilizations switching and program availability)?

REQUIREMENTS/BACKGROUND

Requirements are dictating a configuration of several medium-sized mainframes. It must be determined whether it is more feasible to use these machines by dedicating a function to a given one or letting it float around and be processed on several (batched) as the other processors have resources available.

DESIGN APPROACHES/CHARACTERISTICS

Batched processing is best for an optimum utilization of resources. As was discussed earlier in the network control section, a significant amount of resources saved by having the flexibility to use the resource for many different jobs. Since the network control system will exist, are there any instances in which batched processing should not be used?

ANALYSIS

The control function (set up for purposes of resource scheduling and status) should be applied at a single point within the system. Also, from a security standpoint, it is important that one point be responsible for the allocation of tasks according to security level and to understand what the security status of the system is. Other areas where dedicated processing might be required instead of batched processing include those where a program is used so many times that running the program in and out of memory ends up being a burden on the system. Two examples of this are the data base manager and communications processing. Communication processing depends upon an analysis of the line rates and the variability of the communications processing function based on different lines and different messages types. The final reason is speed. It is important that the network control function operate fast enough so that problems of queueing resources and not dedicating a computer in real-time does not prevent

the requirement from being met. It is thought that if we set a design goal of 5 seconds to respond to high-priority short turnaround tasks, that this is attainable and will prevent the dedication of any computers to the real-time processing of data.

SUMMARY/CONCLUSION

No general statement can be made. Some functions require their dedication to a single processor but for most others batched processing on several processors is adequate.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A214-1, A251-1, A311-10, A342-1 through 10, A641-1, 2, A71-1, A813-1 through 22, A451-13, A331-7, A451-13, A511-7, A513-1, A52-4

4.0 TERMINAL INTERFACE

TRADEOFF TITLE

A40-1: What is the splitup of functions between the communications system, communications computer and main processor?

REQUIREMENTS/BACKGROUND

Areas of responsibility between AFGWC and AFCS (1911 Comm. Sq.) must be clearly defined.

DESIGN APPROACHES/CHARACTERISTICS

OPTION I:

Each communication line coming into GWC is terminated in a modem or other device such as the Data Link Terminals (DLTs) for Autodin. Each of these then is connected to the communications computer. The communications computer is responsible for the following: a) line protocol and maintaining communications over each of the lines; b) formatting the message headers and messages so as to comply with the line protocol for the appropriate communications link; c) identification of incoming messages as to security level and message type; d) assignment of priority in establishing a queue within each priority level; e) message recognition/validation, such as start of message and end of message flags; f) store and forward.

The main processor will be responsible for the following: a) interface with main memories and mass memory; b) message decoding/correcting; c) message and message group validation; d) routing of messages internally within GWC; e) initiation of processors and/or notification of network control.

The communications console is a vital element of this structure. It must interface both with the communications computer as well as with the main processors in order to receive and validate incorrect and garbled messages, both incoming and outgoing.

OPTION II:

Unclassified input information handled by the unclassified communications lines passes directly into an interface box. Network control then determines which main computer will process this unclassified data. Outgoing data for the unclassified lines will follow the reverse path.

Information received over a classified line will first encounter a decoder/router. This equipment will determine the security classification and route it to the appropriately classified interface box. Network Control will determine which computer receives and processes the data so that it remains in an appropriately classified path. For Autodin II, it is assumed that the Datanet 355 operations will include the decoder/router functions. Outgoing data will be switched to the appropriate classified line.

ANALYSIS

(see above)

SUMMARY/CONCLUSIONS

The 1911th Communications Squadron will be responsible for the communications system, the decoder router, and the communications computer, if it is a separate mini. GWC will be responsible for the disk interface device (if not the mini), the disk, the main processor and the communication console. This is documented in Tradeoff Study A40-2.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A811-12

TRADEOFF TITLE

A40-2: What is the division of responsibility between the 1911th Communications Squadron (AFCS) and GWC?

REQUIREMENTS/BACKGROUND

With the current system, the division of responsibility between AFCS and GWC has been difficult to define because System I acts as both a communications processor and a data processor. The division of responsibility needs to be clearly delineated.

DESIGN APPROACHES/CHARACTERISTICS

The line of separation between the two organizations hinges upon the decision relative to the necessity to have mini-computers or only interface devices. Since the Decoder/Routers can handle the basic communications functions, the mini-computers are not required.

ANALYSIS

The 1911th Communications Squadron will be responsible for the communications system and the Decoder/Router. GWC will be responsible for the disk interface device, the disk, the main processor, and the communications console.

The interface between the communications subsystem and GWC should be jointly agreed upon and published by the 1911th and GWC. Some of the types of information to be specified in this document are as follows: a) a method of data transfer with an acknowledgement/non-acknowledgement system; b) the size and format of the data buffers to be handed back and forth; c) flags, routing bits and similar details.

SUMMARY/CONCLUSIONS

With this division, the 1911th Communications Squadron will have responsibility for equipment and circuit performance, as well as operating the communications system. GWC will be responsible for data processing.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A811-12

TRADEOFF TITLE

A40-3: Determine the cost savings and security impact in using RTOS in a classified machine only as a router of lower-level messages to a lower-level configuration.

REQUIREMENTS/BACKGROUND

This is a Univac proposal in which a Univac processor similar to the current System I would be utilized partly as a communications processor and would be established in a secure area.

DESIGN APPROACHES/CHARACTERISTICS

All communications, both classified and unclassified, would enter into this communications processor. RTOS would be used to separate the classified from the unclassified information and the unclassified would be handled by MAXISC and passed on to System II. The classified information would remain in this new front-end system and would be processed there. This would imply a one-way transfer of data base information to the classified computer for processing of the classified information, similar to what is now done in the current System III. Although this separates the security problem into two areas so that there are two levels of classification, it still does not eliminate the problems of mixing different classified levels; that is, confidential, secret, and top secret information. Thus, the system would still be subject to security violations.

ANALYSIS

In order to determine the cost of this alternative, the following assumptions were made. The front processor would be a 1 X 1 1100/40 which equates to RP1.9. Based upon the estimate that 30% of the current System I is utilized solely for communications purposes, this would equate to 16% of an 1100/40. The price of an 1100/40 is approximately 3 million dollars; thus, 16% of the 3 million dollars is $480,000. Because there would be very little change from the software utilized in the current System I, it is estimated that two man months at $4,000 per man month would be required for software development.

This brings the total cost to $488,000. However, in order to provide reliability necessary for this system, a 1 for 1 backup in hardware would be required. Thus, this is another $480,000 bringing the total required for this option to $968,000.

The other alternative is to utilize small computers for the communications functions. To accomplish this, it would require four new minicomputers. The SADPR-85 study accomplished by ESD estimated the cost for a large front end processor system to be approximately $85,000 in 1977. However, based upon current information, it is felt that a more appropriate number is approximately $150,000 for a front end processor system.

Thus, the hardware costs for the four minicomputers would be $600,000. In addition, there would be a requirement for software development, estimated at aprpoximately 10 man years for a total of $480,000. Added to this is the requirement for backup to the main processors in order to provide the necessary reliability. This would be accomplished with two additional processors at a cost of $300,000. Thus, the total cost for this alternative would be $1,380,000.

SUMMARY/CONCLUSIONS

Although the cost of the option using several small processors is over $400,000 more than the option utilizing one large processor, it does offer the advantage of complete separation of the different levels of classification and therefore greatly reduces the chance of any security violations. The selected option is thus to utilize the mini-computers for the communications functions.

It should be noted that neither of the above options include the hardware or software costs associated with the Datanet 355 processor for Autodin II or the Interdata Model 50 processors associated with the Weather Facsimile Switching Center.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

113 - Special Activities - Program D

120 - Special Activities - ZOOM Use

200 - Command Control Systems - All

300 - Emergency War Order Support - All

500 - Space Environment Support - All

602 - General - Mnapower Productivity

RELATED SPECIFICATIONS

A451-1 through A451-22

TRADEOFF TITLE

A40-4 Should message logging be employed?

REQUIREMENTS/BACKGROUND

Message logging would provide a list of all messages received and transmitted, the security classification of each message, and the date and time of receipt or transmittal.

DESIGN APPROACHES/CHARACTERISTICS

Logging could be accomplished either by a large processor or by a small communications processor.

ANALYSIS

This would prove very valuable in the quality control function by helping improve response time of incoming communications and by improving internal GWC procedures. Message logging, however, would increase the software development and the software overhead, as well as increase the requirement for data files in the mass storage associated with the communications processors.

SUMMARY/CONCLUSIONS

The value of message logging should outweigh the increased cost of software and mass storage.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A40-4

TRADEOFF TITLE

A40-5 Should query/response interfaces be standardized?

REQUIREMENTS/BACKGROUND

The future requirements for GWC will demand a vastly increased query/response capability. This is true not only in quantity but also in the shorter time requirements associated with the requests. In addition, a much larger group of users will have access to the automated response-to-query data base. Primarily, this will be through Autodin II and the WWMCCS net.

DESIGN APPROACHES/CHARACTERISTICS

Not applicable.

ANALYSIS

A wide variety of information can be requested by users, primarily requests for computer flight plans. Thus, it is imperative that the query/response interface be standardized.

SUMMARY/CONCLUSIONS

In order to limit the impact of this large requirement, GWC should establish and publish library request codes. These codes will be limited to the minimum number to satisfy the specific requirements of the users. Requests for similar information can thus be standardized and limit the impact on both the hardware and software. This should be similar to the GWC product manual and detail the codes to be used for specific information to be derived from the data base.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

200 - Command Control Systems - All

300 - Emergency War Order Support - All

RELATED SPECIFICATIONS

A41-1, 2, 4, 12, 13

TRADEOFF TITLE

A40-6 What maximum rates should be considered?

REQUIREMENTS/BACKGROUND

Input and output data rates for different users vary widely. Each communications link has a specified data rate.

DESIGN APPROACHES/CHARACTERISTICS

For most of the input and output data from GWC, the data rate is quite low and could easily be handled on lines up to a 4800 baud capacity. However, there are certain future requirements that will require a much higher data rate. These are a 50 kilobaud capacity for Autodin II, a 50 kilobaud capacity for passing satellite data to the Navy Fleet Numerical Center, and a 200 kilobaud capacity for inputting digital radar data.

ANALYSIS

Existing lines handle the GWC data very effectively. Therefore, the only data rates that need to be considered are the new requirements.

SUMMARY/CONCLUSIONS

The system will accommodate line rates of 4800 baud with the following exceptions:

AUTODIN II	50 kilobaud
Satellite data to FNWC	50 kilobaud
Digital Radar	200 kilobaud

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

200 - Command Control Systems - All

300 - Emergency War Order Support - All

401 - Environmental Support - Fleet Weather Central

410 - Environmental Support - Digital Radar

RELATED SPECIFICATIONS

A411-1, A422-2, A425-1

TRADEOFF TITLE

A40-7 What approach should be taken to editing and checking of outgoing messages?

REQUIREMENTS/BACKGROUND

Editing and checking of the weather data is extremely important because the users are demanding more accuracy.

DESIGN APPROACHES/CHARACTERISTICS

Coding and decoding of the weather information is an internal GWC function. Therefore, the terminal interface is not involved.

ANALYSIS

None required.

SUMMARY/CONCLUSIONS

Coding and decoding of messages will be accomplished in the main processors. Editing and checking of the contents of messages will be the primary responsibility of the console operators, as well as of the main processors. When these messages are handed to the communications processor, they will be validated as to format prior to being logged and transmitted.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A40-9, 10, A514-9

TRADEOFF TITLE

A42-1 How will SWI data be handled in the proposed architecture?

REQUIREMENTS/BACKGROUND

Within the special access perimeter, three generic security compartments exist. Precedence has not totally dictated separation of these compartments.

DESIGN APPROACHES/CHARACTERISTICS

The approach which can be taken is to rely on software to maintain the integrity of these compartments as is done in the current System 3 environment with respect to other compartmentalization. The design can be accomplished to provide protection similar to the protection of Secret from Confidential data and other hierarchical security separation accomplished in the normal access perimeter.

ANALYSIS

The number of unique processors required within the AFGWC system is a function of the number of conflicts that can exist simultaneously. We have further confined the problem by indicating that processors can only reside at a special access or a normal access level. The distribution of jobs is such that many more jobs occur at the normal access level thereby allowing us to allocate many more processors to that level and thus provide more flexibility.

The fact that, under the normal operating conditions only a single dual processor will exist within the special access perimeter, less flexibility is provided. We therefore have a strong desire for homogeniety of computer types across the whole system to minimize the cost in providing backup for reliability.

Under these constraints theoretically the ratio of number of jobs to be run in the special access area to those run in the normal access area should be equal to the ratio of number of processors allocated to each of these areas. Even considering noncompartmentalization in the special access area this assumption is not quite true since we feel that job load in special access area actually is less than would be required for the computing power. The

two computers are required there mainly because one is required as reliability backup to the other.

If smaller processors were specified we could reallocate the ratio thereby properly approximating the job load. The specification of a smaller computer however is not consistent with what we feel will be available and most competitive from the various vendors in a procurement.

Further compartmentalization within the special access area even makes matters worse if it is felt that due to conflict three distinct processors must be continually available to the automatic allocation of the network control process. However, based on our analysis of AFGWC requirements, we feel that we can safely make the assumption that the availability of two distinct processors within the special access area and the additional ability to reconfigure the variable perimeter into special access status through manual switching provides adequate responsiveness to meet a three compartmented demand.

SUMMARY/CONCLUSIONS

SDC recommends that the three distinct security levels within the special access area be treated as follows: Two compartments exist distinct but parallel within the hierarchical structure and they are both subordinate to the highest classification level afforded a special access area. The data bases shall remain distinct and the processors shall be allocated to the appropriate classification level with the ability to upgrade data to the highest level, if required. Through switching, a variable perimeter computer can be brought in to accommodate conflicts of up to 4 programs which can be run simultaneously through network control manual switching. Forecaster consoles can be dedicated to any one of the levels through manual switching. The entire data base within the normal access perimeter (with the exception of TSSIOP) is available for processing any of the jobs in the special access perimeter. The capability for a higher level classification data base to overlay the meteorological data base exists at any one of the three levels. The capability also exists to output data resulting from computation and through the security monitor to downgrade certify a lower level of classification to be sent to the appropriate level in any of the normal access communication systems.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No Requirements.

RELATED SPECIFICATIONS

A43-1, A524-1, A821-18, 19

TRADEOFF TITLE

A43-1 Should the option and capability exist to prefilter satellite data based on data base-defined and/or user time criteria?

REQUIREMENTS/BACKGROUND

In the satellite data processing area, it is advantageous to reduce the total system resources needed to fulfill the satellite image processing at AFGWC. Higher selectivity in processing the satellite data would provide a resource reduction.

DESIGN APPROACHES/CHARACTERISTICS

SDC feels that due to the selectivity used in meteorological sensor data gathering operations, the recorded sensor data will never have an exact conformation and content required by the user. If the data do not furnish an explicit user data requirement or aid in the realistic needs of general global forecasting, they could and should be filtered out of the automated processing function. This function can be performed by software just prior or simultaneous to raw data gridding and mapping.

ANALYSIS

Currently 6.53 wall hours (Univac 1110 2 x 1) are utilized to grid and map DMSP visual and infrared data. This time factor is expected to ramain constant into the Block 5D area. TIROS-N will require similar system resources for a total of 13.06 wall hours (excluding fine data processing time). We suspect that elimination of excessive coverage in the high latitude polar regions alone could eliminate ten percent or 1.3 wall hours of gridding and mapping processing. We further suspect that judicial and conscientious filtering could eliminate as much as thirty percent of the gridding and mapping time or 3.9 wall hours.

SUMMARY/CONCLUSIONS

To optimize the use of computer resources for satellite data processing, options should be available to permit prefiltering of satellite data, using data base-defined and/or user time criteria.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

- 100 - Special Activities - All
- 208 - Command Control Systems - TAC
- 300 - Emergency War Order Support - All
- 406 - Environmental Support - Satellite Imagery Dissemination
- 408 - Environmental Support - Interactive Processing and Display System

RELATED SPECIFICATIONS

None

TRADEOFF TITLE

A43-2 Should the Satellite Image Dissemination Subsystem (SIDS) interface be a minicomputer, normal handling of tapes, or a direct interface with the mapping and gridding function (input and output)?

REQUIREMENTS/BACKGROUND

AFGWC currently provides several satellite imagery products to external customers. The techniques now utilized for that dissemination are inadequate for the future customer needs and data volumes. AWS has presented a plan for that distribution; the plan was generated based on current AFGWC system architecture and in our opinion does not lend itself to growth indicated by the Task 1 requirements analysis.

DESIGN APPROACHES/CHARACTERISTICS

The following options are candidates for the imagery distribution system:

Option A - Manual operation as presented in the AWS/SID plan, 1974.

Option B - Semi Automated System which would receive inputs from manual visual products and computer reconstituted products, the latter transferred to the SID over remote tape devices.

Option C - Automated System driven by minicomputer. Data would still be received from manual sources but would be held to a minimum. Most products would be reconstituted by the Satellite Image Generation Subsystem (SIGS) and transferred directly to the SIDS minicomputer.

ANALYSIS

Option A Cost

24 hour manning for three operators is estimated to be $300K per year (one scheduler and two operators). For the 1977 - 1982 time frame, this will amount to $1.8 for manning. Hardware costs (excluding the communications equipment) are estimated at $100K.

Total approx. $1.90M

Option B Cost

24 hour manning for 2.5 operators (one scheduler and 1.5 operators) is estimated at \$250K per year. For the 1977 - 1982 time frame this will total \$1.5M for manning. Hardware costs (excluding the communications equipment) are estimated at \$150K.

Total approx. \$1.65M

Option C Cost

24 hour manning for one operator is estimated to be \$100K per year. For the 1977 - 1982 time frame, this will be \$600K for manning. Hardware costs (excluding communications equipment) will be \$300K plus \$200K software development cost and \$10K per year software maintenance costs.

Total approx. \$1.16M

SUMMARY/CONCLUSIONS

Option A and B are deemed to be too costly due to manpower, requiring several operators per shift.

Option C is retained; once programmed, this will provide a system that will require one operator per shift. Manual inputs will be input via laser scanner to mass storage. Reconstituted inputs will be transferred from the SIGS existing in a main processor. The mini will also be the scheduler of product output and control output protocol, all requiring minimum operator control. The system will easily handle increased phaseover to a higher percent of reconstituted products as available.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A444-1, A515-1

TRADEOFF TITLE

A43-3 Should the capability exist to interface raw ungridded data with the SID interface?

REQUIREMENTS/BACKGROUND

AFGWC must distribute satellite imagery products in a timely and accurate manner. This will be accomplished by the Satellite Image Dissemination Subsystem (SIDS).

DESIGN APPROACHES/CHARACTERISTICS

Option A - Interface SIDS to the raw data storage

Option B - Provide SIDS with gridded imagery produced by the vehicle dedicated interface subsystem (Site III, DUS, etc.) and computer reconstituted imagery.

ANALYSIS

Reasons for discarding Option A.

a. Programming costs to develop software to: (1) selectively retrieve data from the raw data files, and (2) reconstitute imagery;

b. Information available on raw data files will be available in gridded form within minutes of its availability on raw storage; and

c. All imagery to meet requirements can be supplied by option B.

SUMMARY/CONCLUSIONS

Option A is discarded. SIDS will utilize option B. Option B provides products primarily in the form of imagery products reconstituted from the gridded satellite data bases, supplemented by gridded data from the vehicle dedicated interface subsystem. As AFGWC expands the gridded satellite data bases phase-over to more reconstituted products will occur.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

120 - Special Activities - ZOOM Use

406 - Environmental Support - Satellite Imagery Dissemination

RELATED SPECIFICATIONS

A515-1

TRADEOFF TITLE

A43-4 Should satellite data be gridded and mapped on-the-fly utilizing array processors or should the processing continue to utilize current techniques and an upgraded central system processing with buffering?

REQUIREMENTS/BACKGROUND

A major problem facing AFGWC during the 1977-1982 time frame is the ingestion, gridding and mapping of DMSP, TIROS-N and GOES satellite data. Currently, AFGWC grids and maps the HR and IR 2nm data available from DMSP. During the 1977-1982 period DMSP data will be available at 1.5nm (smoothed) and .3(fine) nm resolution. Similar data will be available from TIROS-N in 1978. GOES data will also be available in 1976.

This tradeoff is based on the following requirements provided to SDC on guidelines in this study:

a. Total processing of all DMSP and TIROS-N smoothed data.

b. Three percent processing of DMSP fine data in 1978 and ten percent in 1980.

c. The processing of five (20° x 20°) windows of GOES data in 1977.

The daily data volume associated with these requirements are:

DMSP (2 vehicles)

Smoothed 266 x 10^6 words/day
Fine data 23.94 x 10^6 words/day (1978)
Fine data 79.8 x 10^6 words/day (1980)

TIROS-N

Smoothed 266 x 10^6 words/day
Fine data (not required)

GOES

42 readouts 2142 x 10^6 words/day

DESIGN APPROACHES/CHARACTERISTICS

Two options to be evaluated are on-the-fly gridding and mapping utilizing array processors and buffered gridding and mapping utilizing central system processors. The tradeoffs dealing with the array processor in the buffered approach are quite similar to those presented for the on-the-fly array except the buffered array cost would have to additionally reflect the storage costs. Both concepts are fully compatible with the remainder of the system architecture.

ANALYSIS

Acquisition costs for an on-the-fly system capable of handling simultaneous inputs for the three satellite programs are as follows:

Array processing

DMSP	2	ea. at .5M
TIROS-N	1	ea. at .5M
GOES	1	ea. at .5M

Software Development

DMSP	1M
TIROS-N	.5M
GOES	.5M

Integration, Engineering, Interfacing Hardware		$1M
	TOTAL	$5 million

Acquisition Costs for Enhanced Buffered System

Preprocessor

Hardware	2 at 250K ea.
Software	250K ea.

Mass Storage

10 disk (Univac 8433)	36K ea.
2 controllers	100K ea.

Integration, Engineering and Interfacing Hardware $500K

TOTAL $1.81 million

NOTE: Approximately $236K of this equipment is currently in inventory at AFGWC.

The following are time estimates for gridding and mapping on the Univac 1100 (2 x 1):

a. 3.5 min. (wall time) per quarter orbit for smoothed data mapped at approximately 3nm resolution

b. 30 min. (wall time) per 2/5 orbit for fine data mapped at approximately .3nm resolution (maximum recorded data per orbit)

DMSP GRIDDING AND MAPPING TIME

Smoothed Data

14 revs · 4 quarter orbits per rev · 3.5 min · 2 vehicles = 392 min. per day

Fine Data

10 revs · 30 min. · 2 vehicles = 170

1978 three percent = 18 min. per day

1980 ten percent = 60 min. per day

TIROS-N GRIDDING AND MAPPING TIME

Smoothed Data

(Same as DMSP) 392 min. per day

GOES GRIDDING AND MAPPING

42 readouts per day · 11 min per readout = 462 min. per day

Total gridding and mapping time for DMSP, TIROS-N and GOES in 1980 (maximum requirement) is 1306 minutes (Univac 1110 time).

On-the-fly gridding and mapping would require dedicated resource during ingest. The time estimates are then based on 2.5 min. readout time per smoothed orbit and 10 min. per fine orbit. Total dedicated time for TIROS-N and DMSP is

DMSP

(2.5 min per orbit on the 14 orbits · 2 vehicles = 70 in.)

(10 min. on 10 orbits per day · 2 vehicles = 200 min.)

(3 percent = 6 min and 10 percent = 20 min.)

The total time to grid and map fine data would not add to the time since the requirement for fine data are less than the time required for smoothed data.

TIROS-N

2.5 min. on 14 orbits per day · 2 vehicles = 70

GOES

5 min. per readout (estimated) · 42 readouts per day = 420 min. per day

NOTE: This is the time required to grid and map GOES on-the-fly and would account for total gridding and mapping and not just the required 5 (20° x 20°) areas. The array would be required to perform continuous gridding and mapping in order to extract the fine data windows.

Total on-the-fly processing time = 350 min. or 5.8 hours.

Time estimates for GOES processing are not available and these are not addressed in this tradeoff.

In the enhanced architecture, the central system processor will have core sizes sufficiently large to increase the number of map boxes being mapped by a factor of 6 to 8. This would enable the gridding and mapping system to overlap I/O. Currently approximately 80 percent of this wall time is I/O wait time. It is feasible that the time required to grid and map on the enhanced central system could be reduced to 20 to 30 percent of the run time due to overlap of I/O. At 30 percent, this would reduce the run time to 6.5 hours compared to 6.8 run time for the on-the-fly system.

SUMMARY/CONCLUSIONS

The array processor utilized in either the buffered approach or the on-the-fly approach does not potentially provide enough marginal speed increase to warrant the expectations of an additional \$3.3M to \$3.5M. The satellite data gridding and mapping should be optimized by increasing the central system processor storage capacity in order to implement significant I/O overlays.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

- 100 - Special Activities - All
- 208 - Command Control Systems - All
- 406 - Environmental Support - Satellite Imagery Dissemination
- 408 - Environmental Support - Interactive Processing and Display System

RELATED SPECIFICATIONS

None

TRADEOFF TITLE

A44-1 What is the tradeoff between the use of one large communications processor versus several small ones?

REQUIREMENTS/BACKGROUND

The current system uses System I as a communications computer. This causes a large software overhead within the Real Time Operating System (RTOS) and overloads the core memory. In addition, all security classifications except special access are operated upon in this system, violating the security separation requirement. Security requirements dictate that there shall be the least possible mixing of levels of classification.

DESIGN APPROACHES/CHARACTERISTICS

One approach to use two large computers with revised software to provide as much security as possible. The second approach is to use small computers as front ends for the large computer systems, each of them dedicated to a security level.

ANALYSIS

If dedicated security level processors are used, the quantity required is based on the number of distinct security paths. The security paths are special access, SWI, Top Secret, and SPECAT (which can be treated as Secret). The communications processors must be consistent with the various levels of messages which can arrive or be originated at GWC: Unclassfied, Confidential, Secret, Top Secret, SWI, and Special Access.

The philosophy followed in this design is to determine the classification of message as soon as possible in the processing and to switch it into the appropriate path or if message classification cannot be determined, to output it on the communications console. This reduces the mixed mode processing and the exposure of one level of classification to other levels of classification in the data base and the computer programs. Doing this results in less chance for compromise due to either hardware error or to malicious

action through software. In the same vein, output messages should not be switched to the data line until the last possible minute. The switching function should be independent, and should be performed by an isolated hardware/software function.

SUMMARY/CONCLUSIONS

It is not consistent to have a large interface processor for communications. Instead, a switch based on initial security determination, and then a small communication processor at the level of the path into which the message is switched, should be employed. These small processors will provide flexibility and classification level security.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A41-5, 6, 9, 11

TRADEOFF TITLE

A44-2 Should priority of message be considered in processing?

REQUIREMENTS/BACKGROUND

In addition to various security levels transmitted over the communications lines, messages of different priorities are used. These consist of the normal DOD priorities; e.g., routine and immediate, as well as time response priorities established by the users.

DESIGN APPROACHES/CHARACTERISTICS

(See ANALYSIS)

ANALYSIS

It is important that the communications processor recognize the priority of the incoming and outgoing messages so that it can establish a queue within each priority level. Communications processors should also obtain priority interrupts so that the highest priority message is operated on first.

SUMMARY/CONCLUSIONS

The operating philosophy in the communications subsystems shall be a first-in first-out activity at each priority level.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A41-2

TRADEOFF TITLE

A44-3 What approach should be taken to decode/checking of the incoming data?

REQUIREMENTS/BACKGROUND

Weather data received by GWC is in the form of messages with the information encoded. Thus, the data must be decoded and verified prior to being usable in the data bases.

DESIGN APPROACHES/CHARACTERISTICS

Decoding/checking can be completely automated or accomplished by a man/machine combination.

ANALYSIS

This function is performed internal to GWC. When the communications console receives an incoming message, it will take the following steps to check the data: a) check parity, b) identify the type of message, c) validate the format of the message, d) check the priority prior to entering the data into an appropriate queue, e) check the security level in order to pass the data along the proper GWC security link.

Questionable messages upon which the communications processor cannot act will be passed to the communications console for action; or retransmission will be requested prior to handoff of the data to the GWC main processor.

The main processor then will take the following actions prior to processing the data: a) decide which decoder is appropriate, b) decode the message, c) examine the message text, and d) validate the message.

SUMMARY/CONCLUSIONS

Decoding/checking is a necessary function that will be performed under the control of the communications console.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A514-1

TRADEOFF TITLE

A44-4 Should only headers be certified for communications data or should there be more extensive message checking capabilities?

REQUIREMENTS/BACKGROUND

In communications interfaces such as AUTODIN, error checking is relied on to establish the security level of a message. In general, there is a man injected in the loop, however, to further certify proper classification of the message. In an automatic data system interface, a question arises as to whether more checking is warranted.

DESIGN APPROACHES/CHARACTERISTICS

Presently, only the headers and the individual buffers or segments which make up messages are checked. The checking could be expanded to further recognize total message structure and content.

ANALYSIS

There is not adequate standardization to allow checking for structure or content at the present time. Many messages are manually originated, thereby imposing more rigid constraints on the message generator. The opportunity does exist to standardize WWMCCS messages. However, this would only be a small subset of the total traffic. According to a consensus of those associated with the present system and others investigating the problem, the checking of communication headers and buffers is thought to be adequate and the invention of further checking would be of little improvement over the current approach.

SUMMARY/CONCLUSIONS

SDC proposes that no additional checking be accomplished.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A41-1

TRADEOFF TITLE

A44-5 What processor configurations should be used for the line handler/ decoder routers?

REQUIREMENTS/BACKGROUND

In the architectural design there is a requirement for a line handler/decoder router computer which interfaces with all lines of a given maximum security level. In some instances the computers have already been specified (for example, the Data-Net 355 for AUTODINII). The functions to be performed by this computer include:

a. Line-specific interfaces which for non-intelligent line termination includes all line protocol and synthronization tasks and for lines with intelligent terminals it includes prespecified interfaces.

b. System specific message decoding to determine message security level and to ensure message begin and end conditions.

c. This processor must perform the routing function which includes selecting a channel corresponding to the correct security classification, authentication of the channel, gaining access to the appropriate disk on which the message is to be written and finally writing the message onto the disk.

d. The line handler/decoder router has the task of interfacing with the communications console. When it recognizes that messages are to be manually processed or that security checking is not satisfactory, it automatically routes the message to the communications console.

DESIGN APPROACHES/CHARACTERISTICS

Based on a) requirements, b) cost, c) confusion in trying to reverse current data line interface decisions; the approach seems straight forward. That is, to utilize a mini computer which can perform the functions specified, with special consideration given to computers already intended for use minimize backup costs and achieve software development cost savings. The key characteristics in the decision are the ability to insure proper routing and the ability to interface with the disk subsystem.

ANALYSIS

The options for interface with the disk depend on the controller selection. Assuming the use of a standard disk controller then there must be some way for the communications computer to know where the data should be written. This can be provided by the computer reading a file of the disk which provides this information or it can be provided by a natural cascading of files for individual computer whereby the timing disallows the possibility of a communications computer writing over the unprocessed data of another. A final solution is the existence of a write lockout to the communications buffer area which is removed when the data are processed.

SUMMARY/CONCLUSIONS

We feel that since the specification of the exact intercommunications between the line handler/decoder router and the classified disk depends on the features and capabilities of the disk subsystem that the specification should be written to reflect this.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A113-3

TRADEOFF TITLE

A44-6 Should packet switching capability be used for security/application routing?

REQUIREMENTS/BACKGROUND

Various high speed switching techniques are being considered by the Defense Communications Agency for use on the Autodin II System.

DESIGN APPROACHES/CHARACTERISTICS

Packet switching is a method of making efficient use of transmission lines and uses store and forward techniques. The messages are subdivided for efficiency in transmission into short segments called packets of about 100 characters in length. These packets are transmitted through multiple switching centers from source to destination. At each switching center or node, the packet is stored in core memory for only a few milliseconds and then routed along dynamically determined paths. Each node maintains a continuously updated routing table so that packets can be easily routed at each switching center along the path which most efficiently minimizes transmission delay at that moment. When a message is transmitted it is subdivided into packets and transmitted to the destination along any available network path. Each packet proceeds along its own path until it reaches its destination where all packets are stored. The complete message is reassembled for delivery to the receiving host or terminal.

ANALYSIS

The ARPANET is currently using this approach. The other application of this technique would be in Autodin II which will involve a very large network of users (particularly the WWMCCS net). In this application the Datanet 355 will act as a terminal interface processor and divide messages into packets for transmission and reassemble received packets into complete messages. For minimal handling of information at the various security levels that will be transmitted through Autodin, the Datanet 355 will be connected directly into the GWC system.

SUMMARY/CONCLUSIONS

To support the WWMCCS network in 1980, GWC will employ the Autodin II network. The GWC interface with this network would be through a Datanet 355 controller at GWC, and appropriate hardware and software must be incorporated for this interface.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

- 113 - Special Activities - Program D
- 115 - Special Activities - Agency B
- 200 - Command Control Systems - All
- 300 - Emergency War Order Support - All

RELATED SPECIFICATIONS

A411-1

TRADEOFF TITLE

A45-1 To what extent should protocol be standardized?

REQUIREMENTS/BACKGROUND

Line protocol affects the complexity of the software required to operate on the incoming messages and format the outgoing communications. In addition, the multitude of external links use different protocols which compound the problem.

DESIGN APPROACHES/CHARACTERISTICS

A standardized message protocol for all external GWC messages would greatly simplify the communications software.

ANALYSIS

On all the existing communications links, the protocol has already been established and is in operation. Therefore, little can be done to change it except for future possibilities with new requirements. However, on new systems such as Autodin II, there is a possibility that GWC can influence protocol to be established on the line. This would be particularly important with high data rates such as the Autodin II at 50 kilobaud and even more so on the digital radar which is expected to have data burst rate of 200 kilobaud. There is a strong effect of protocol on the software involved in the communications processor. By establishing the protocol or influencing the protocol, GWC can have a much simpler approach to software development.

SUMMARY/CONCLUSIONS

GWC should take a very detailed look at the protocol possibilities available with these new systems and standardize wherever it is possible, then let this influence the older systems whenever changes are made to those links.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All requirements.

RELATED SPECIFICATIONS

A461-1

TRADEOFF TITLE

A46-1 Should the interface with all facsimile systems be the Interdata 50?

REQUIREMENTS/BACKGROUND

In data automation requirement no. AFCSJ-74-4 dated 1 February 1975, the Air Force Communications Service has proposed a weather facsimile switching center (WFSC). The purpose of the WFSC is to replace the manual facsimile operation at GWC and enable the weather facsimile functions at the National Meteorological Center at Suitland, Maryland to be incorporated into the system at the AFGWC. This will provide total automation from a centralized CONUS weather facsimile facility.

DESIGN APPROACHES/CHARACTERISTICS

For automation of its facsimile operations, the National Weather Service is currently employing an Interdata Model 50 minicomputer. In order to utilize this information directly, the Air Force Communications Service has purchased their own Interdata Model 50 which is located at the National Meteorological Center at Suitland, Maryland. It is currently being programmed by the AFCS personnel with the assistance of the personnel from the National Weather Service who already have software operating. This will provide complete compatibility between the facsimile transmission systems of both the Air Force and the National Weather Service.

ANALYSIS

In order to complete the compatibility and establish a centralized facility for the Air Force, the Air Force Communications Service is proposing the purchase of two Interdata Model 50s, to be located at AFGWC for transmission of facsimile products throughout the Air Force networks. After the two Interdata Model 50s are installed and operating at GWC, the unit at the National Meteorological Center will be moved to Offutt as a backup to the two at that facility. Thus, the Interdata Model 50 will be utilized for all facsimile transmissions from GWC. Some of these transmissions will be automated and will be generated at the automated work centers, while others will be manually prepared facsimile

products which will be handcarried to the WSFC for the AFCS personnel to digitize and then transmit through the Interdata 50s.

SUMMARY/CONCLUSIONS

Forecaster consoles which produce facsimile products will be connected to the Interdata 50s which will interface with all of the facsimile circuits.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

412 - Environmental Support - Weather Facsimile Switching Center

RELATED SPECIFICATIONS

A472-1

5.0/6.0 CONSOLES/DATA INPUT AND DISPLAY

TRADEOFF TITLE

A50-1 What method should be utilized for providing and updating information to the AWCs?

REQUIREMENTS/BACKGROUND

The Automated Work Center (AWC) processors must interface to the main system processors. The AWCs are divided into (a) those that require a highly responsive interface and (b) those where the response may be delayed in the seconds range. The AWCs in the first class also, due to security guidelines, require a dedication to a particular system processor or are connected to all the system processors in a parameter. The second class of AWC will not require system dedication because the jobs associated with the work centers are scheduled on various system processors.

DESIGN APPROACHES/CHARACTERISTICS

The direct interface AWCs will utilize dedicated system processor I/O channels. The channels will be connected via ICCU-type devices and utilize normal intercomputer software interrupt protocol. Incompatibility between the wordlength of the AWC support processor (16, 32, or 36 bits) and the wordlength of the system processor (32, 36, or 60 bits) would require special software and/or hardware for format compatibility. Switching for these AWCs will occur infrequently; normally once or twice per day via manual network control switches.

The indirect or "mail-drop" interface AWCs will be connected via multiple-accessed storage devices (disks). The disks will be multiported to the AWC support processors and to the system processors. Job requests from these AWCs will be "mail-dropped" onto the disk system and in parallel routed to Network Control (NC) via one-way communication links that are multiplexed into the NC processor. Products in response to these requests will also be "mail-dropped" on disk by the assigned or scheduled system processor. This "mail-drop" will be periodically (approximately once per second) queried by the AWC processors for requested products. The products will be retrieved and distributed to the requesting console and stored on local main storage devices.

ANALYSIS

Two major factors affect the interfacing of AWCs to system processors: (1) the responsiveness of the interface and (2) the desire to maintain as much flexibility of scheduling system processors as possible. These two factors in the extreme cases are not totally compatible. That is, in order to obtain an extremely fast response the responding processor must be directly tied to the requestor. In this case scheduling would exist only within the dedicated machine and not between the available system processors. If more flexibility is desired it implies time delay; delay due to scheduling a processor, allocating the job, and disk drop and retrieve (twice).

The variability of AFGWC AWC responsive requirements and task require that the interfacing techniques not rely on only one method. Therefore both methods of interface will be used at AFGWC.

The following AWCs will require direct dedicated interface to at least one system processor.

a. Network Control

b. Computer Operation

c. Security Monitor Output Stations

d. Software Development and Studies/Analysis. (Note: the nature of "off-the-shelf" software development systems require dedication processors.)

The following AWCs will utilize the disk implemented "mail-drop" interface technique:

a. Forecaster Consoles

b. Special Operations

c. Quality Assurance

d. Remote Job Entry

SUMMARY/CONCLUSION

Those techniques utilized to provide information to the AWCs is based on the desire to provide a responsive and flexible interface.

Therefore, the methods chosen are (1) dedicated communication paths to AWCs which primarily require responsiveness and (2) a "mail-drop" disk communication technique for the AWCs that do not require responsiveness in milliseconds but for which flexibility is desired.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

120 - Special Activities - ZOOM Use

406 - Environmental Support - Satellite Imagery Dissemination

408 - Environmental Support - Interactive Processing and Display System

RELATED SPECIFICATIONS

A20-6, A313-1 through 17, A50-1, 2, A511-3, A20-5, A513-4, A514-6, A515-4

TRADEOFF TITLE

A51-1 What are the tradeoffs associated with a centralized operations console versus independent ones?

REQUIREMENTS/BACKGROUND

Operations consoles which survey and to some extent control the status of GWC's computer systems can be placed as monitors for individual computers or groups of several of them. The factors which will determine the number and placement of the ops consoles must be determined.

DESIGN APPROACHES/CHARACTERISTICS

This study will consider two possible levels at which ops consoles might be placed:

a. at the level of the individual computer

b. at the level of the perimeter (with only special access and normal access perimeters being considered)

ANALYSIS

Keeping in mind the precedent established by the positioning of the Network Control Consoles solely in the Special Access Perimeter, it seems a logical next step to place the ops consoles in areas where they can act as centralized monitors within their perimeters. This would suggest an ops console in the special-access perimeter and another in the normal-access perimeter. Under such a configuration, the levels at which console-monitors exist include: network control, operations consoles, and individual computer processors.

This decision to centralize ops consoles is also strengthened by the network control principles which will allow functions to float from one computer to another within a given perimeter as computer resources dictate. This means that the individual computer may not be able to even continually monitor the health of one function, it will take an ops monitor at the perimeter level to make that determination.

SUMMARY/CONCLUSIONS

Operations consoles should be placed in centralized positions in both the special-access and normal-access perimeters.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A512-1

TRADEOFF TITLE

A51-2 Should we consider interactive satellite image compression/rejection for display?

REQUIREMENTS/BACKGROUND

The fully automated, consistent, and accurate extraction of useful meteorological phenomena from remotely sensed data is currently beyond the state-of-the-art. In fact, criteria for automation have not yet been established. In the current time frame, the remotely sensed data are presented to the meteorologist in a pictorial format, either on a CRT or more commonly on photographic/facsimile hardcopy. The existence, recognition, and identification of meteorological characteristics containing useful information are manually performed by a perusal process. This process is performed manually for both static and dynamic (i.e., time dependent) characteristics. In the latter, time-lapsed sequences are prepared for perusal by a meteorologist in either motion-picture film formats (becoming rapidly obsolete) or by refreshing a CRT. The determination of wind vectors from cloud motions derived from selected cloud locations in successive GOES data frames is a current technique exemplifying the use of time-lapsed sequences to extract information from dynamic meteorological phenomena.

DESIGN APPROACHES/CHARACTERISTICS

The attainment of capabilities for fully automated extraction of useful meteorological information for remotely sensed data would be a desirable achievement. An ability to automatically extract pertinent meteorological information would subequently enable the following cost conserving advantages to accrue:

a. Reduction in the number <u>and</u> talent level of required meteorological operational personnel (including their training cycle).

b. Minimization of computational growth requirements resulting from elimination of data that do not contain useful meteorological information (this activity is closely related to efforts concerned with development of data rejection algorithms applied during the

initial data-stream processing. The problems of data compression are different from those of data rejection).

c. Reduction of time intervals between data input and resulting output of significant meteorological information to enable faster turn-around where meteorological information is perishable (to either the end user as a product, or as initial condition input values for exercising numerical analysis or forecast models).

ANALYSIS

To achieve automated information extraction it is necessary to establish quantitative criteria and to then invoke numerical pattern recognition and/or signature analysis principles, probably employing both structured and non-structured techniques. A meteorological (numerical) filter(s) would have to be developed for the various types of information to be extracted from the remotely sensed data. This activity can be significantly enhanced by providing a semiautomated (i.e., interactive) capability for the learning process. Once the filter has been established and tested, it can be applied to the operational data stream to automatically extract the meteorological information for which it was designed.

SUMMARY/CONCLUSIONS

GWC should develop the capability for interactive satellite image compression/rejection for display. It may be required to achieve automated meteorological information-extraction capabilities and the associated long-term operational cost reduction advantages.

RELATED REQUIREMENTS

This Trade Study is related to the following requirments:

120 - Special Activities - ZOOM Use
406 - Environmental Support - Satellite Imagery Dissemination
408 - Environmental SUpport - Interactive Processing and Display System
602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A52-11

TRADEOFF TITLE

A52-1 What features should exist in the forecast console?

REQUIREMENTS/BACKGROUND

GWC has identified a tentative plan for a computer-assisted, semiautomated METWATCH. One goal of the METWATCH concept is to minimize the number of personnel required to manually prepare and format supporting information required by a meteorologist for analysis and forecasting activities.

DESIGN APPROACHES/CHARACTERISTICS

The use of interactive CRT consoles, controlled and operated by a forecaster, supported with computation and display generation facilities has been identified as a viable approach for subsequently minimizing manual information and chart/map preparation while simultaneously enabling the forecaster to retain the flexibility required to prepare meteorological analyses and forecasts.

ANALYSIS

The forecaster will, under his control option, observe selected data sets presented on a CRT(s) and accept, reject, modify and/or combine the presented information to enable him to formulate a custom-tailored data set for meteorological analysis and/or forecast for output to the user. The forecaster will have available input devices such as digitizing tables, trackball, and keyboard for entering control-and-command functions and for inputting data. A refresh memory will be included as part of the console configuration to store data to be presented on CRTs. Since satellite and/or ground radar imagery and graphics information are needed by the forecaster, the console configuration will probably need both raster and vector type CRTs. Overlay capabilities for "wedding" graphics to satellite/radar information would also be required. This capability must be supported with frame-to-frame registration techniques.

Some of the supporting operating capabilities required to enable the forecaster to manipulate the information are:

Zoom or window

Encode subset areas by controlling a cursor

Pseudo coloring

Split screen

Roll frame

Overlay

Erase (selectively)

Blink

Trace

Vary resolution

Threshold

Priority establishment

Accessibility to a variety of data bases

SUMMARY/CONCLUSIONS

The capability shall exist which will allow the forecaster to observe selected sets of data presented on CRT(s) and accept, reject, modify, and/or combine the presented information to enable him to formulate a custom-tailored data set for meteorological analysis and/or forecast for output to the user.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

113 - Special Activities - Program D

115 - Special Activities - Agency B

217 - Command Control System - Crisis Management

406 - Environmental Support - Satellite Imagery Dissemination

408 - Environmental Support - Interactive Processing and Display System

511 - Space Environment Support - OTHB Radar

602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A52-2 through 4, A52-7 through 15, A52-17 through 19

TRADEOFF TITLE

A52-2 What is the tradeoff between alternative programmer interfaces with the data system?

REQUIREMENTS/BACKGROUND

The types of programmer interfaces with the data system must be identified. The advantages and drawbacks of each must be determined.

DESIGN APPROACHES/CHARACTERISTICS

The two kinds of programmer interfaces considered in this study are:

a. remote run card entry readers
b. remote terminals

ANALYSIS

Programmers can maintain their source statements on cards kept in their office which are either manually submitted to an operation desk or entered into a remote-run entry card reader. SDC does not recommend this approach to interfacing programmers with the data system for several reasons:

a. Card decks are cumbersome and get lost or scrambled, decreasing programmer productivity.

b. Card handling requires additional operations personnel.

c. A programmer will tend to keep only one copy of a program, which he will submit. Afterwards, he cannot continue to work on the program, and must switch to another one or be idle. With online programming, he can easily compile and test changes to one subroutine while continuing to work on an extra, temporary copy of the code. He can thus maintain his continuity of thought, and overlap his compilation and test runs with other work.

d. With programmers keeping individual source desks, it is nearly impossible to create and maintain a software catalog to maximize reuse of existing routine.

e. Interactive software development replaces the batch-card interface.

Remote terminals are required to support online software development. These terminals should be placed in the programmers' offices and operated in local mode over coaxial cable to an unclassified processor. The terminals should consist of a CRT with an alphanumeric keyboard attached. A few (one or two) typewriter terminals may be desirable for hardcopy; this is particularly useful in an interactive debug mode. The CRT terminals can be shared between pairs of programmers.

Remote high-speed printers are seldom desirable due to the high noise level of mechanical printers.

Remote terminals can be shared between several programmers without significant inefficiencies. The actual ratio can only be established through experience, and is heavily dependent on the type and amount of software activity going on at the GWC as a starting point. Considering that, on the average, one of the five will not be present to use the terminal due to TDY, leave, or training, the remaining four will each have two hours per day of terminal use.

SUMMARY/CONCLUSIONS

The use of remote terminals is recommended for programmer interface with the GWC data system. Remote run card entry readers are not considered to be advantageous devices for programmer use.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A528-1, 2

TRADEOFF TITLE

A52-3 What is the tradeoff between storage support and capability for the forecaster consoles?

REQUIREMENTS/BACKGROUND

It has already been established that the desirable features on the forecaster consoles will include the accessing, displaying, and modifying of large portions of the data base (see A54-1). This will require additional disk storage associated with the minicomputers acting as interface between the central data base and the forecaster console. The amount of storage required may be a limiting factor on the console abilities.

DESIGN APPROACHES/CHARACTERISTICS

For this study, it will be assumed that the minicomputer interface between the central data base and forecaster console will be similar to the Interdata 8/32. Disk storage available for this computer consists of drives with 2.5, 10, and 40 x 10^6 byte capacity. One control unit is capable of handling up to four disk drives. The following table lists prices of this hardware:

Storage Capacity (bytes x 10^6)	Disk Drive Cost	Control Unit Cost
2.5	$4,000	$6,000
10	$4,500	$8,500
40	$7,000	$17,750

ANALYSIS

Forecaster consoles will be expected to accept, reject, modify, and/or combine presented information with the goal of formulating a custom-tailored data set. This will require an ability to plot any data base field from any geographic area.

If a minicomputer interfacing between data base and forecaster console is allocated a control unit with a 4-40 x 10^6 byte disk drives (at an additional cost of $45,750) it would have the storage area equivalent to about 1/6 of the meteorological data base or large enough to hold the entire gridded global data base of smooth DMSP data.

Even if the forecaster should require data from more than 1/6 of the data base, (and such situations should be rare), the data base manager will be given the ability to filter data by type and resolution before passing it on. This will tend to reduce the amount of storage needed for the forecasting console to do its work. Under these considerations even the one control unit with 160 x 10^6 bytes storage becomes a very liberal upper bound.

SUMMARY/CONCLUSIONS

Required storage support should not be a limiting factor on capabilities for the forecaster consoles.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

113 - Special Activities - Program D
115 - Special Activities - Agency B
120 - Special Activities - ZOOM Use
217 - Command Control Systems - Crisis Management
406 - Environmental Support - Satellite Imagery Dissemination
408 - Enviornmental Support - Interactive Processing and Display System
511 - Space Environmental Support - OTHB Radar

RELATED SPECIFICATIONS

A52-8, A111-1

7.0 PERSONNEL

TRADEOFF TITLE

A70-1 How can the shortage of qualified Air Force programmers be alleviated?

REQUIREMENTS/BACKGROUND

One of the biggest problems at GWC is a shortage in manpower, primarily qualified Air Force programmers. Personnel authorizations are inadequate and current manning is even below those. Approaches which will allow GWC to meet requirements with this shortage of human resources must be investigated.

DESIGN APPROACHES/CHARACTERISTICS

The major problem in AFGWC software development is the general lack of manpower to satisfy user dictated requirements. Several factors contribute to this problem.

a. The military rotation policy prevents significant long term continuity in the software development.

b. The nature of the task requires a specific mix of skills. Many of the programming positions require advanced knowledge in meteorology and significant programming skills as well. Some of the software problems require skilled system programmers; however, most system programmers at AFGWC have meteorology backgrounds.

c. Low manning dictates less time devoted to training, both training for newly assigned personnel and advanced training for the experienced programmers.

The following figures indicate current under-assignment of personnel. NOTE: Only 76 percent of the authorized programming positions are currently manned.

AFGWC Programmer Manning[1]

Branch	Auth	Assigned	
WPD	112	80	71%
WPE	5	4	80%
WPJ	11	10	91%
WPP	11	11	100%
WPA	28	22	79%
Total	167	127	76%

d. Inadequate personnel authorization. Estimates by AFGWC for required manning to accomplish the "Deficit Tasks" indicate that additional personnel are required to fulfill the requirements in a timely manner to satisfy customer's needs. The following figure contains the estimated undermanning by Branch. The specific requirements are contained in the AFGWC Deficit Tasks memo.

Estimated Undermanning[1]

Branch	Undermanning
WPA	6 man years
WPE	5 man years
WPF*	40 man years
WPD	18 man years
Total	69 man years

*Forecasters, rather than programmers.

Most of these problems are inherent in the system but can be solved by increasing productivity.

[1]As of April 1975.

ANALYSIS

The current number of GWC programmers (engaged in direct programming efforts) is approximately 127 (see paragraph 6 above for branch breakout). These programmers are engaged in three types of activity: maintenance, enhancement and development.

Currently the training program for the programmer consists of a six week training course taught by UNIVAC. Once the programmers have completed the UNIVAC course, they are assigned to a duty section. The assignment to a specific section is based on their background, skills and interest. Subsequent training is accomplished while on-the-job and basically consists of assignments that increase in difficulty as the programmer's skills improve in response to more experience.

The following profile of the "average GWC programmer" was developed from the response to the SDC software development questionnaire in March, 1975. One hundred and eleven (111) questionnaires were completed by programmers that were assigned to GWC. This profile is a general model and is an average of all the questionnaires. Some of the numbers have been adjusted to compensate for obvious errors in the responses or misinterpretation of the questionnaire.

It is important for the reader to note this profile is an average and is not necessarily congruent with any specific programmer at AFGWC. For further information on programmer profiles, several sample section profiles at AFGWC are also attached, as Tables 7.1 - 7.5.

Table 4. Average AFGWC Programmer Profile

Lines of Fortran code responsibile for in	(maintenance)	7086
	(enhancement)	1141
	(development)	1131
Lines of Assembly code responsible for in	(maintenance)	7050
	(enhancement)	2593
	(development)	209
Percentage of Total Individual's Effort	(maintenance)	29%
	(enhancement)	23%
	(development)	48%
Turnarounds per week		12.1
Average number compilations and/or assemblies per	build run	5.95
	build/execute run	4.54
Average number of executions per	execute run	1.74
	build/execute run	1.89
Average compilation size (Fortran)	lines of code	943
Average Assembly size	lines of code	145
Collections (link edits) per	build	3.28
	execute	3.48
Execution parameters per build or build/execute	words of core	31K
	CPU time (seconds)	152.3
	wall time (seconds)	475
Average number of tapes utilized per run	programs	1.3
	data	.5
Average tracks of mass storage per run		433
Average cards utilized per run		108
Average of print per run		115

Table 5. Average WPP Programmer Profile

Lines of Fortran code responsible for in	(maintenance)	5409
	(enhancement)	1955
	(development)	781
Lines of Assembly code responsible for in	(maintenance)	436
	(enhancement)	473
	(development)	182
Percentage of total Branch's effort	(maintenance)	35
	(enhancement)	20
	(development)	45
Turnaround per week		18
Average compilations and/or assemblies per	build run	6.4
	build execute run	2
Average number of executions per	execute run	5
	build/execute run	2.5
Average compilation size (Fortran)	lines of code	1982
Average assembly size	lines of code	231
Collection (link edits) per	build	2.4
	execute	2.8
Execution parameters per build or build/execute	words of core	38K
	CPU time (seconds)	72
	wall time (seconds)	308
Average number of tapes utilized per run	programs	2
	data	.7
Average tracks of mass storage per run		213
Average cards utilized per run		151
Average pages of print per run		151

Table 6. Average WPA Programmer Profile

Lines of Fortran code responsible for in	(maintenance)	619
	(enhancement)	644
	(development)	3600
Lines of Assembly code responsible for in	(maintenance)	---
	(enhancement)	60
	(development)	---
Percentage of Total Individual's effort	(maintenance)	3
	(enhancement)	11
	(development)	86
Turnarounds per week		9.7
Average number compilations and/or assemblies per	build run	6.75
	build/execute run	8.25
Average number of executions per	execute run	4
	build/execute run	4.6
Average compilation size (Fortran)	lines of code	1063
Average assembly size	lines of code	36
Collections (link edits) per	build	10
	execute	3.75
Execution parameters per build or build/execute	words of core	68.1K
	CPU time (seconds)	409
	wall time (seconds)	781
Average number of tapes utilized per run	programs	1.6
	data	1
Average tracks of mass storage per run		125
Average cards utilized per run		156
Average pages of print per run		115

Table 7. Average WPD/RTOS Programmer Profile

Lines of Fortran code responsible for in	(maintenance)	1950
	(enhancement)	25
	(development)	150
Lines of Assembly code responsible for in	(maintenance)	4188
	(enhancement)	225
	(development)	125
Percentage of Total Individual's effort	(maintenance)	45
	(enhancement)	27
	(development)	28
Turnarounds per week		8.1
Average number compilations and/or assemblies per	build run	21
	build/execute run	16
Average number of executions per	execute run	1.1
	build/execute run	1
Average compilation size (Fortran)	lines of code	274
Average assembly size	lines of code	456
Collections (link edits) per	build	3.8
	execute	3.8
Execution parameters per build or build/execute	words of core	81K
	CPU time (seconds)	421
	wall time (seconds)	3188
Average number of tapes utilized per run	programs	5.5
	data	1
Average tracks of mass storage per run		1110
Average cards utilized per run		124
Average of print per run		134

Table 8. Average WPJ Programmer Profile

Lines of Fortran	(maintenance)	7600
	(enhancement)	172
	(development)	890
Lines of Assembly	(maintenance)	60
	(enhancement)	--
	(development)	--
Percentage of Total Individual's effort	(maintenance)	8
	(enhancement)	13
	(development)	79
Turnarounds per week		24.75
Compilations and/or Assemblies per	build run	4.0
	build/execute run	6.5
Number of Executions per	execute run	1
	build/execute run	1.25
Compilation size (Fortran)	lines of code	240
Assembly size	lines of code	--
Collections	per build	1
	per execute	1
Execution parameters per	build or build/ execute	
	words of core	54K
	CPU seconds	275
	wall time seconds	640
Tapes utilized per	execution	1
	programs	1
	data	2
Tracks of mass storage		120
Cards utilized per	execution	44
Pages of print per	execution	155

SUMMARY/CONCLUSION

The only obvious solution to handle GWC's personnel problems are more personnel. Since this does not seem to be an approach with which the Air Force will comply we must work toward increasing the workload and output of individual programmers. The means which make this route possible include more software and hardware programming tools, more uniform programming and documentation techniques, and a more sophisticated programmer training program (see Trade Study A85-2).

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

406 - Environmental Support - Satellite Imagery Dissemination

408 - Environmental Support - Interactive Processing and Display System

602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A528-1 through 12, A72-7, A921-1

TRADEOFF TITLE

A70-2 Should programming be Air Force or contractor?

DESIGN APPROACHES/CHARACTERISTICS

Pertinent conclusions made in Appendix VI to Volume 3 of the SADPR-85 study are as follows:

ADL (Arthur D. Little, Inc.) cites the following sources from which the Air Force might acquire software during the SADPR-85 period of interest.

- Commercial sources (including hardware vendors) might be used for acquisition of standard, off-the-shelf, software packages from which systems could be assembled in "building block" fashion.

- Contract programming firms might be hired to write application and system software to Air Force specifications.

- Air Force programming organizations might provide software design and implementation services.

Ultimately, it is expected that software elements will be acquired from all of the above sources, although ADL predicts that the most cost effective approach would include use of pre-packaged software to the maximum extent possible (consistent with the Air Force's unique requirements).

ANALYSIS

Analysis conducted under SADPR-85 include the following:

When contracting houses are selected as software sources, the Air Force would have to expect to pay $20-$30 per programmer hour. Offsetting the high costs associated with these sources is their high man-hour productivity, which ADL estimates to be 50 percent to 100 percent higher than in-house Air Force sources.

There are certain classes of software which should be developed exclusively by Air Force personnel. These include new versions of applications programs with which Air Force programmers are already intimately familiar, and those systems programs whose logical procedures and structures directly reflect specific Air Force policies and methods of operation (message switching software, for example). The level of effort, and therefore the costs associated with in-house software development, will become clearer when a) the software entities to be developed in-house have been identified, b) productivity of Air Force programmers has been analyzed more completely, and c) the effect of new software engineering techniques has been estimated.

REQUIREMENTS/BACKGROUND

GWC will have an ever-increasing need to develop new software to meet user requirements. GWC, however, will also be faced with a shortage of qualified programmers. This, in fact, may be typical of a problem that will be prevalent in much of the Air Force. Attention was directed to this situation in a study recently sponsored by the Air Force Electronic Systems Division entitled "Support of Air Force Automatic Data Processing Requirements Through the 1980's (SADPR 85)." This report identifies the total automatic data processing (ADP) requirements of base level organizations (i.e., USAF operational support organizations below the major command headquarters level) through the 1980's, provides feasible automatic data processing system (ADPS) concepts and alternative system configurations for satisfying those requirements, and suggests an implementation plan for the options chosen.

Since the SADPR-85 Data Project Directive called for planning a system for implementation in the late 1970s and early 1980s, an understanding was needed of the data processing and communications capabilities and costs likely to be available at that time. Previous technology forecasts generally dealt with components and the state-of-the-art in research and development. SADPR-85, however, must be able to be implemented. Therefore, the technology of interest must have been proved by application and must be described in terms of system components which will be available on competitive bids from ADPE vendors.

The Study Team understands that a controlled data base for use with the Data Automation Planning and Resource Management Information System is under development, and that within the next year it should yield valid assessments of current manpower needed to perform system analysis, programming, test, and maintenance tasks. The resultant manhour figures, gathered at the Air Force Data Systems Design Center, will then be used to estimate the manpower needed for future software development efforts.

SUMMARY/CONCLUSIONS

It appears that a judicious mix of commercial sources, contract programming firms, and Air Force programming organizations would provide the most cost-effective approach to procuring required software. While maximum use of "pre-packaged" software is encouraged, GWC will be required to implement a large percentage of new and unique software for a wide variety of applications and system support requirements. The optimum mix of Air Force-contractor programming for applications software should await the results of Air Force studies that will determine:

a. exact identification of the software entities to be developed,

b. productivity of Air Force programmers has been analyzed,

c. effects of new software engineering techniques have been estimated.

A summary of some of the prime candidates for vendor or outside contractor supply in the support area are indicated in Table 7.6.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

100 - General - All
208 - Command Control System - TAC
216 - Command Control System - AWACS
218 - Command Control Systems - Computer Flight Plans
300 - Emergency War Order Support - All

RELATED REQUIREMENTS (Cont'd)

400 - Environmental Support - All

500 - Space Environment Support - All

602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A331-1 through 18, A72-7

Table 9. Sources for Major New Support Software Packages

	POSSIBLE VENDOR OR CONTRACTOR SUPPLY	POSSIBLE AIR FORCE SUPPLY
NETWORK CONTROL	*	
DATA BASE MANAGEMENT	*	
COMMUNICATIONS MANAGEMENT	*	
GENERALIZED AUTOMATED WORK CENTER INTERFACE		*
STUDY ANALYSIS LANGUAGE/SYSTEM	*	
PROGRAMMER INTERFACE	*	
SECURITY CONTROL		*
BENCHMARK SOFTWARE FOR PERFORMANCE MONITORING	*	
HARDWARE/SOFTWARE DIAGNOSTICS	*	

TRADEOFF TITLE

A71-1 What is the personnel requirement based on the automatic work center design?

REQUIREMENTS/BACKGROUND

A distinct need exists to automate the operations of GWC as much as is feasible. This is especially important in the light of the possibility of reduced manning levels and the need to accommodate ever-increasing user requirements. To fill this need, the concept of Automated Work Centers (AWCs) to support operator actions has been developed. These centers will be specialized, but the equipment for each AWC will be assembled from a battery of standard devices (e.g., CRTs and plotters) that will be a part of the selected GWC architecture. Categories of these AWCs are:

a. Forecasting centers,

b. System control centers, and

c. System support centers.

DESIGN APPROACHES/CHARACTERISTICS

AWC design considerations and guidelines include the following:

a. Minimizing the total number of operations,

b. Relative costs of automation vs manual techniques,

c. Segregation of work areas into normal and special access areas,

d. Implementation of the system network control concept,

e. Tradeoffs between centralized and dedicated support centers,

f. Desirability of interactive software development and remote job entry,

g. Ease of phaseover, and

h. Tradeoffs between central computers and minicomputers for interrupt handling.

Analyses have considered these guidelines in conjunction with the basic assembly of AWC hardware components specified for these architectures to develop required numbers of personnel to man these positions.

ANALYSIS

The number of personnel allocated to each of the console positions is based on the following rationales:

a. Forecasting Centers

As indicated in Table 7.7, numerous classified and unclassified Forecaster Consoles will be manned by WPF, WPE, and WPJ personnel. The WPF and WPJ functions are assumed to be sufficiently complex to warrant two operators per shift. In WPF, teams would consist of one assisting observer and one forecaster per center, while WPJ would man their centers with two man "technician-meteorologist" teams to fulfill their functions. WPE centers would occasionally require 2-man teams to perform operations but the average should not exceed one man.

Automation should cause a reduction in the WPF observer staff. It is assumed that six observer positions (slots) can be eliminated through automation by 1982.

b. System Control

Table 7.1 indicates that network control, computer operations, and communications consoles will each be manned by 2 WPD men. In each of these 2-man teams, activities will be shared between skilled technicians of approximately equal capabilities with one acting as the senior man in charge. (These functions are judged to be sufficiently complex to warrant two men per console to adequately monitor and control required operations). Security monitoring, however, can be accomplished with one man per console, while the maintenance consoles will on the average be manned less than 50% of the time. In addition, a console for remote

Table 10. Console Personnel Allocation

Work Center Category	Function	No. of Consoles	Personnel Per Console	Slots Per Shift	Total Slots	Primary GWC Org
Forecasting						
	TAF-MET (UNCLASSIFIED)	17	2	34	170	GF
	SESS (UNCLASSIFIED)	2	1	2	10	SF
	SESS (CLASSIFIED)	1	1	1	5	SF
	SX (CLASSIFIED)	4	2	8	40	SX
System Control						
	NETWORK CONTROL	1	2	2	10	AD
	COMPUTER OPS	2	2	4	20	AD
	COMM	2	2	4	20	AD
	MAINT	5	***	2	10	AD
	SECURITY MONITOR	2	1*	2	10	AD, SX
	REMOTE JOB ENTRY	1	-*	-*	-*	-*
System Support						
	SPECIAL OPS	1	2	2	10	AD
	QUALITY ASSURANCE	1	1	1	5	AD
	PRINTER CONTROL	1	0.5	0.5	2.5	AD
	ARCHIVAL CONTROL	1	0.5	0.5	2.5	AD
	SATELLITE DATA SUPPORT	2	2	4	20	AP
	SID	2	2	2	20	AP
	SOFTWARE DEVELOPMENT	30	← AS REQ'D →			AD, SA
TOTALS		72		71**	355**	

*RJE console monitor by a security monitor console operator
**Plus use by AD, SA personnel as required.
***An average loading of two men for the five maintenance consoles is assumed.

job entry monitoring can also be maintained by the WPD operator in charge of the normal access security monitoring console.

In addition, it is expected that WPD can experience a reduction of two programmer slots for program development due to automation. This is based on the assumption that of the 70% of the 100 programmers in WPD involved in program maintenance about 3% can be eliminated due to automated techniques.

c. System Support

Special operations, satellite data support, and satellite imagery dissemination are all sufficiently complex functions to warrant two highly qualified operators; possibly one officer and one skilled technician per console. Quality assurance, however, can be accomplished with one WPD operator, while a single WPD operator should be sufficient to cover both printer control and archival control functions. There will be numerous consoles devoted to software development to be used on an as-needed basis by WPD and WPA personnel.

Automation should reduce the required levels of WPA and WPD programmers involved in new program development. In WPA, of the 70% of the 20 programmers doing new program development (14 programmers), about 20% (3 men) could be eliminated. In WPD assuming 30% of the 100 programmers are involved in developing new programs, and assuming 20% of these can be eliminated via automated techniques, a net WPD savings of 6 could result.

SUMMARY/CONCLUSIONS

Table 7.1 summarized the numbers of personnel associated with the various forecasting system control, and system support consoles, and expands these figures to total personnel slots by using a factor of 5 to permit 24 hour a day - seven day a week coverage. It is important to note, however, that

although many of these positions are new to GWC in concept (e.g., network control), automation and its resulting efficiencies will permit existing personnel to perform these functions. In fact, some net reductions in manning will occur. Table 7.8 summarizes personnel allocations on an organizational basis, indicating the percentages of organization personnel that will be involved with Automated Work Centers. Overall, it can be seen that well over half of the personnel in these six line organizations will be actively using these Automated Work Centers to perform their duties.

Table 11. Impact of Automation On Selected GWC Organizations

ORG	ASSIGNED SLOTS-1975	INCREASED 77-82 REQ'TS*	1982 EXPECTED MANNING**	SLOTS SAVED THRU AUTOMATION	NET SLOTS 1982**	SLOTS EMPLOYING AWCs 1982	% OF SLOTS EMPLOYING AWCs**
WDF	263	20	283	6	277	170	61%
WPE	26	5	31	-	31	15	48%
WPJ	64	-	64	-	64	45	70%
WPD	189	7	196	8***	188	85****	45%****
WPP	40	20	60	-	60	40	67%
WPA	23	2	25	3	22	Used as Req'd	As Req'd
	605	54	659	17	642	355****	55****

* Based on new user and model requirements

** Assuming increases to 1975 level only to directly meet new requirements.

*** 2 for program maintenance,
6 for program development

****Plus use of software development consoles as required

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

120 - Special Activities - ZOOM Use

217 - Command Control System - Crisis Management

406 - Environmental Support - Satellite Imagery Dissemination

408 - Environmental Support - Interactive Processing and Display System

602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A20-1, 2, A50-4 through 8, A511-2 through 8, A512-5 through 8, A513-9, A514-1 through 5, A516-1, A52-10 through 18, A525-4 through 7, A526-1, A527-3 through 9, A528-11, 12, A529-3 through 5, A813-1, 6, A813-16 through A813-23, A71-1 through 6, A72-1 through 8, A73-1

8.0 MANAGEMENT

TRADEOFF TITLE

A81-1 Should there be modifications to the AFGWC organizational structure and associated responsibilities?

REQUIREMENTS/BACKGROUND

As assessment has been made of the AFGWC organizational structure by evaluating the impact of major new requirements on GWC operations. Consideration has also been given to the effect of the new data system architecture, including the implementation and integration process, on staff and line operations personnel.

DESIGN APPROACHES/CHARACTERISTICS

As stated in the Task 1 briefing, SDC considered the basic AFGWC organizational structure that existed at that time to be adequate; that is, the breakdown into four staff organizations (DA, DO, IN, and CCQ), two field locations (OL-A and OL-B), and seven Branch organizations (SA, AP, SX, AD, GF, SF, and LG) appeared to be well suited to GWC missions and responsibilities. For the most part, SDC still believes that the newly proposed overall GWC organizational heirarchy, which includes ETAC, Carswell, the Second Weather Squadron, and the Moffett operating location, is well organized to meet GWC responsibilities. (This proposed structure is shown in Figure 8.3). However, within certain elements of these organizations, some restructuring is possible to optimize GWC operations under the new architecture. The three major units that appear to be affected organizationally are:

a. Operations Staff (DO) Primarily because of responsibilities to implement and validate new hardware and software;

b. Data Acquisition and Processing Branch (WPP) Primarily because of requirements to process greater amounts of satellite data of different types and because of requirements to distribute this data through the Satellite Information Dissemination System; and

c. Data Automation Branch (WPD) Mainly due to a reorientation of personnel to man Automated Work Centers for machine operations (along with maintaining associated software), and to develop software to meet several new model and user requirements.

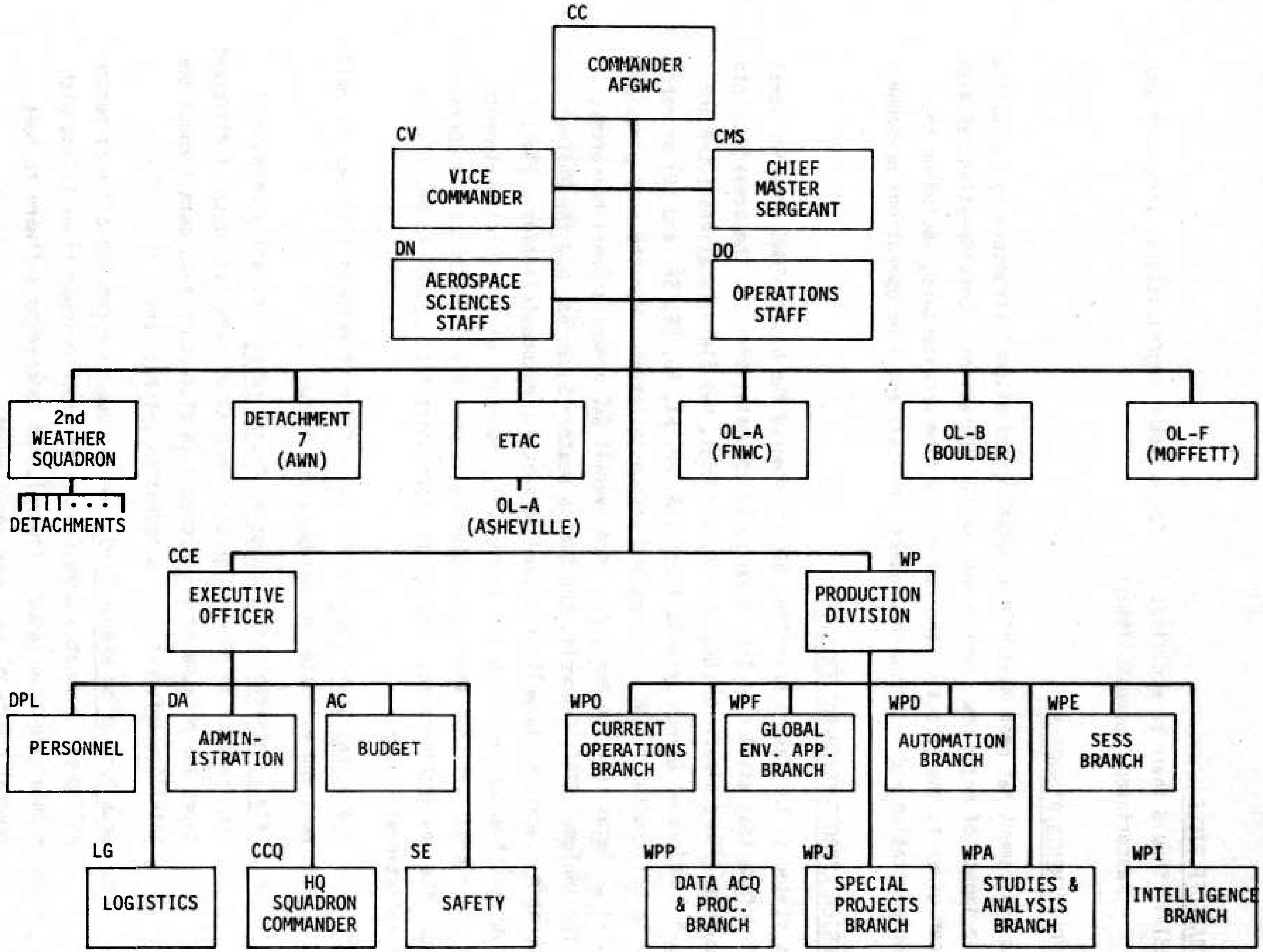

Figure 1. Current AFGWC Organizational Structure

ANALYSIS

Except for DO, no consideration has been given in this trade study to restructuring GWC liaison or staff organizations. Most of the functions of these units are employed to maintain administrative efficiency within GWC, and are not expected to require changes as a result of a new data system architecture or new requirements. DO, however, will probably realize an expanded role as new data system components are acquired, integrated, and validated. Thus, as illustrated in Figure 8.4, it is suggested that distinct responsibilities be set up within DO for acquisition/integration and configuration control (configuration control is often structured as one subset of integration activities, but since these kinds of hardware and software maintenance activities are so critical to GWC, this function should be given key prominence in the DO staff). The day-to-day functions of Production Division operations support, as well as requirements analysis and planning activities, will remain as primary responsibilities of DO, as shown in Figure 8.4. In keeping with this new long-term enphasis on data system integration, a suggested new title for this entity is the "Operations and Integration Staff".

It should be noted that in accomplishing software configuration control, DO will be involved with both in-house and outside contractor personnel. DO will therefore be in the position of enforcing established Air Force configuration management guidelines on contractor personnel, as well as controlling the production and maintenance of in-house software. All products should be documented, produced, and maintained according to a consistent set of standards. The enforcement of these rules should be the responsibility of DO. To enable this configuration control and contractor management, DO may require a staff that is more oriented towards the computer sciences and systems engineering. This increased emphasis on computer systems analysis backgrounds will not only ensure the success of computer systems implementation, but will also further guarantee the success of other related long-term planning efforts.

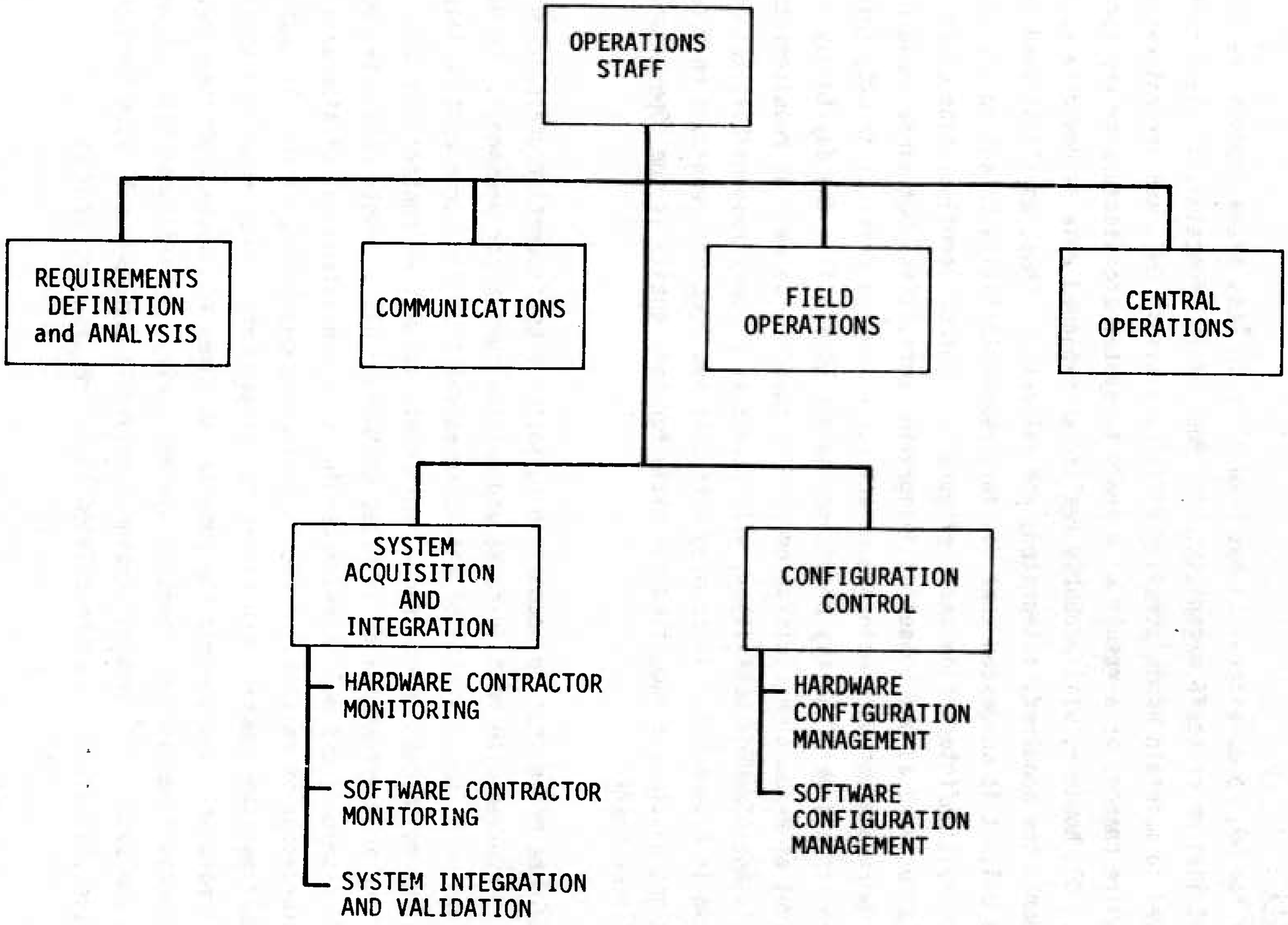

Figure 2. Operations Staff Organization

Most of the Branch organizations in the Production Division need not necessarily undergo realignment because of the new requirements or because of a new architecture. While some requirements and proposed hardware and software components may profoundly affect the ways in which activities are accomplished, these tasks can, for the most part, still be done under current personnel hierarchies. The Studies and Analysis Branch, for example, will be involved in the development of numerous new models over the next several years, but as is the case now, there will be much overlap between computer scientists, mathematicians, and meteorologists in this area, many of whom will simultaneously be involved with more than one computer program. A rigid structuring, therefore, of this branch does not appear to be justified.

The same is true of the Special Projects, Space Environmental Support, and Intelligence Branches: activities within these organizations, even considering the impact of the new architectures, should still be feasible within current organizational frameworks. Similarly, while forecaster consoles, new models, and new user requirements may greatly change the methods by which observers and forecasters execute their duties, these methods should be accommodated by the present structure. That is, teams of observers and forecasters, generally allocated to geographical areas, should still be a reasonable way to operate.

The Data Acquisition and Processing Branch, however, can benefit from some reorientation at the lower levels to reflect the impact of satellite data input and output requirements. As shown in Figure 8.5, Operations and Program Development sections are reasonable divisions of responsibility within the Branch, but within each section, processing of new data sources and the semi-automated dissemination of this processed data should receive special attention. A suggested more descriptive title for this Branch is "Satellite Data Processing Branch".

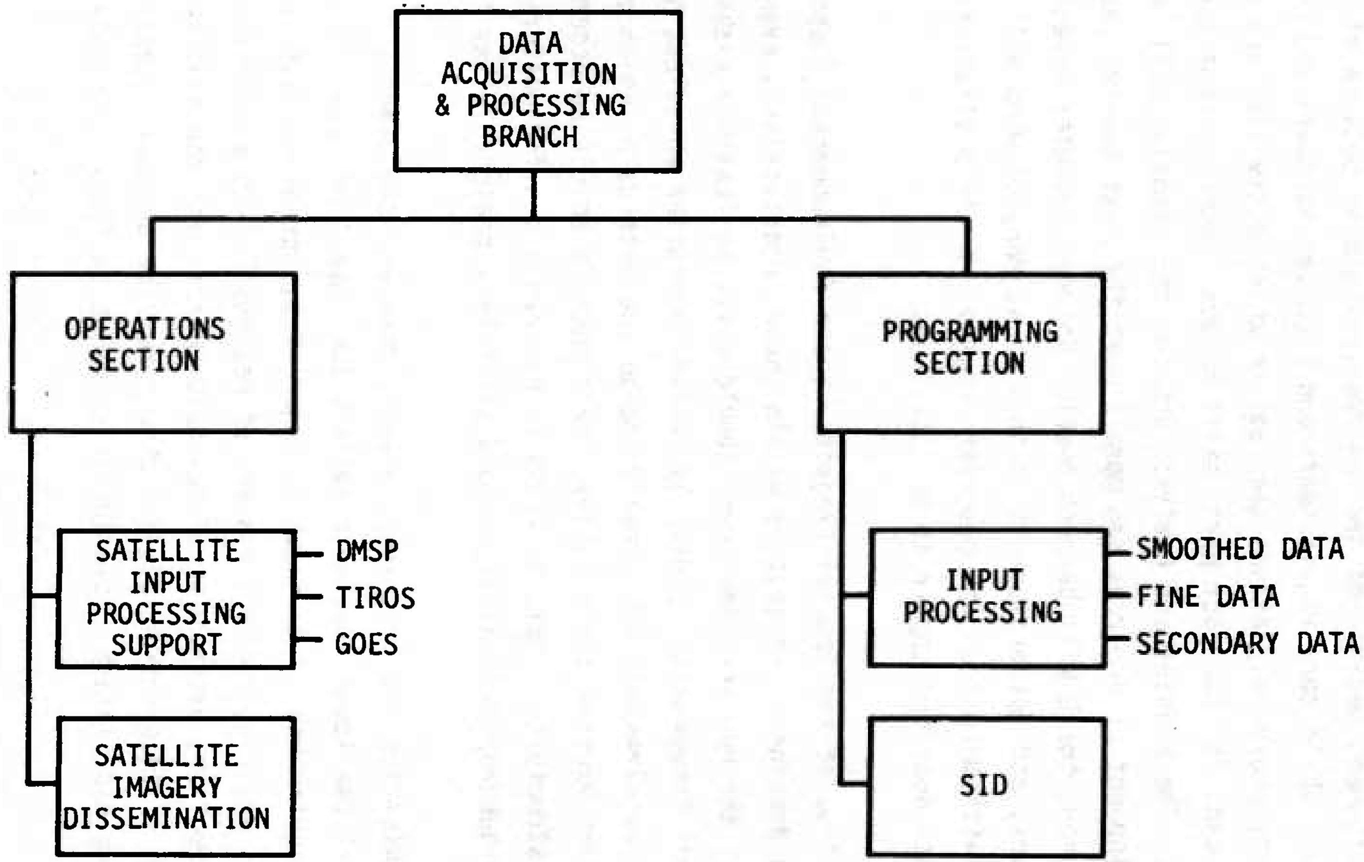

Figure 3. Revised Data Acquisition and Processing Branch Organization

Figure 8.6 illustrates several suggested changes to the Data Automation Branch structure:

a. Machine Operations Section. This new structure reflects the advent of numerous Automated Work Centers that will be used by machine operations personnel.

b. Computer Flight Plans Section. No changes anticipated - this function will take on more importance with the influx of new CFP requirements in the 1977-82 time frame.

c. Mission Applications Section. This section has been structured to emphasize some of the major new software development and maintenance efforts that will be required.

d. Environmental Data Systems Section. No basic changes, although this section's substructure has been set up in part to emphasize the large development efforts that are expected in data base software and in executive program conversion.

e. Data Handling Section. This entity was retitled from its former name of "Data Processing Section" to more accurately describe its present and proposed functions. Its structure is intended to allocate personnel to the coding, conversion, and maintenance of front-end decoders and to the development of software for new communications processing functions.

f. Operations Support Section. This is a new unit within this Branch, and is oriented toward any development and/or maintenance that will be required of GWC to accommodate the functions of the system control and system support Automated Work Centers. In the more distant future, this group could develop software for other specialized operations, such as unique support for the Interactive Processing and Display System, that might supplement contractor efforts.

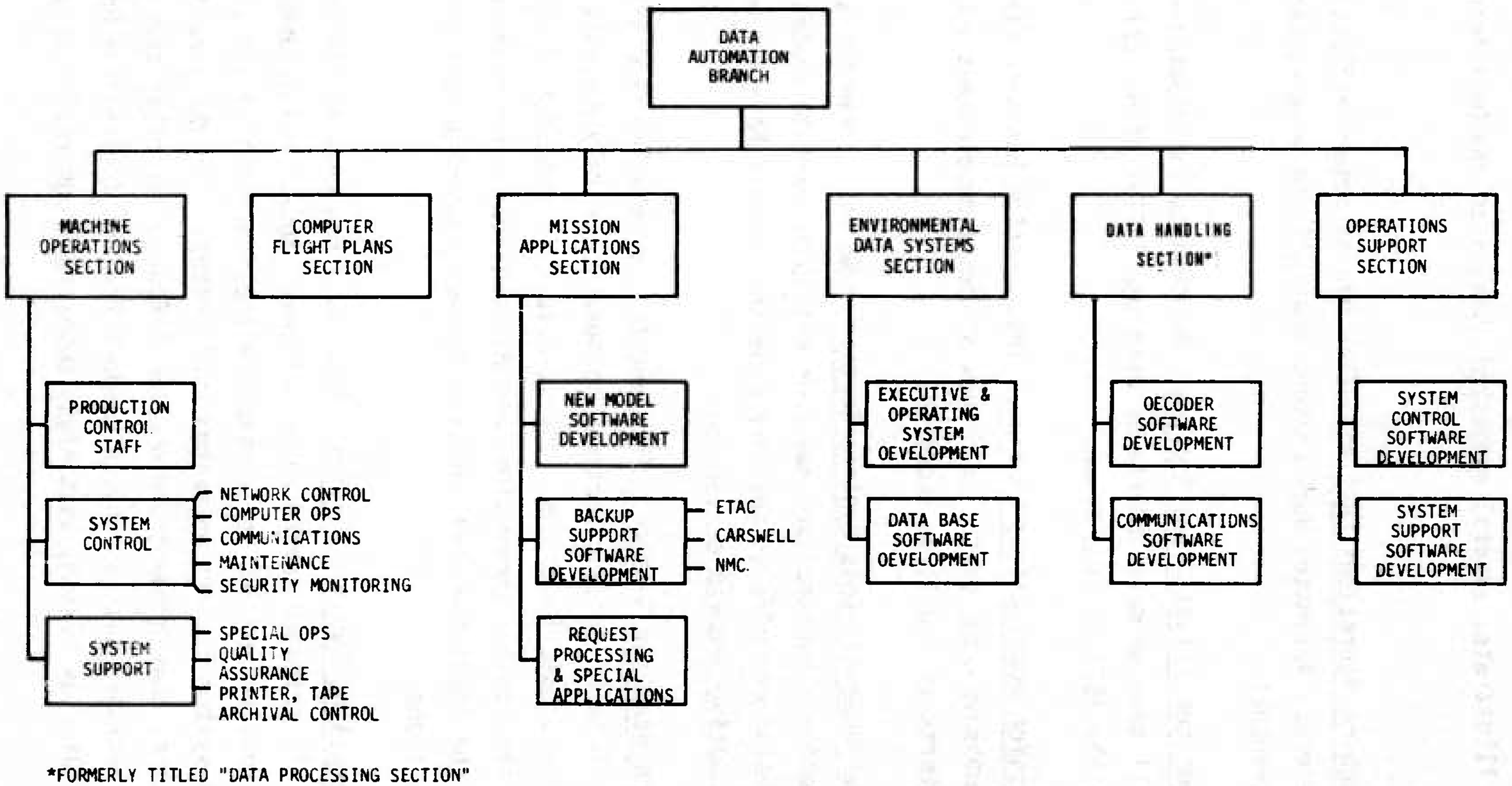

Figure 4. Revised Data Automation Branch Organization

Two technically-oriented organizations that are new to the AFGWC structure are the Aerospace Sciences Staff, which will report directly to the commander but will work in close conjunction with the Studies and Analysis Branch, and the Current Operations Branch, which will closely monitor the production efficiency of the Division (especially the operations of the Global Environmental Applications Branch) by working with all line organizations. Both of these units will further serve to guarantee the success of the AFGWC mission through efficient advanced analyses and more thorough quality control.

SUMMARY/CONCLUSIONS

Most 1977-82 requirements can be accommodated with modest changes to the GWC organizational structure as currently proposed. Greater emphasis should be placed on acquisition and integration activities in the operations staff (now recommended to be reporting to the commander of all AFGWC operations), on the input and output of satellite data in the current Data Acquisition and Processing Branch, and on new responsibilities in the Data Automation Branch. While the nature of activities within other Branches may be greatly affected by the new architecture, these new tasks can be accomplished within current organizational frameworks.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A811-1 through 12

TRADEOFF TITLE

A81-2 What is the level to which operations management is considered in developing the network controller concept?

REQUIREMENTS/BACKGROUND

The concept of network control is a change from current operations. Specifically it takes scheduling activity away from the man as a real-time function and automates it. He must therefore preplan. The changes in operation management are critical to the operations of GWC.

DESIGN APPROACHES/CHARACTERISTICS

Several things were considered in conceiving the Network Control System: a) minimum deviation from current organizational entities and individual responsibilities were assured; b) the present task scheduling technique was totally automated providing more efficiency wherever possible; c) a simple control data base was established so that the Network Controller could know precisely what priority decisions would be made and would only have to intervene in the automated process when the previous plan was no longer valid; d) the inability of the operating components to individually or totally meet tasking demands is immediately brought to the attention of the Network Controller.

The Network Controller is the person responsible for the data system. In the operational organization, he is in charge of individuals manning the operational console position, the security monitor position, the comm control position (not the entire comm function), and the maintenance function. The role is more centralized to the degree that one person is responsible for activities in both computational perimeters (normal and special access).

One of the most significant changes in new data system concepts over old ones is the ability to reconfigure and to automatically provide the capability to upgrade and downgrade computers prior to accomplishing a task of another security classification. Any time there is a configuring of physical entities into logical entities, this produces an additional burden on the network

controller in his requirement for visibility of the system. This is the area where human factors of the network control console will be key in the design.

ANALYSIS

A network control scenario might help clarify the network control function and its management aspects. We must assume that the system exists at some arbitrary state in terms of resource assignments to each other and to security level. There is a central queue which is the master task scheduler under the control of the network control computer and available for reference by the Network Controller. When a task is to be run, the desire to run it is entered into this queue.

Each task has stored in the data bases certain characteristics parameters (or they are assumed). These include security level, activation time (if not current), distribution of run time, ability to be interrupted, time period within which the task must be run, any special links to other tasks, and security level of the task.

A dynamic priority queue is utilized. This means that when items are entered into the queue they are done so according to a priority level. If desired, the priority label can change as a function of time (i.e., age). As a job gets closer to its due time, then its priority will increase. Due time itself is a parameter which may be entered in a variety of ways, either linked with another task, or entered as an absolute.

Whenever a job is to be run, a resource is sought. The Network Control Monitor scans activities within each system component. Based on nominal times, it knows when the component will become available. It also knows what the present classification level is and whether a change is needed to run the task in the queue. There is also an indication of other factors which might make beneficial uses automatically of what's left.

The role of the human interface (i.e., Network Controller) during this time is a monitoring or override function. He has the capability to determine resource assignments, task assignments and the status of each task as compared to the nominal or average characteristics of that task. His manual control function is simply one of being able to modify any of the scheduling control parameters. He may change the priority or characteristics associated with any of the jobs, thereby causing it to be processed differently. He can limit the configuration options associated with the hardware components by modification of the configuration option list. He can reserve components by removing them from action or he can isolate a component set for a checkout or maintenance function. He is indeed in complete control of data system activities.

The ability to constrain the number of options available for system configuration is important. One can specify a configuration exactly like the one that exists at GWC today, i.e., where processors are always configured to a certain security level. Or the system can be configured to its maximum efficiency (greatest changeability). If desired, the amount of switching of components or security downgrades can be minimized through constraining the reconfiguration options.

SUMMARY/CONCLUSIONS

Operations management is changed to the extent of:

a. consolidating the operational control function,

b. putting preplanning parameterization in place of real-time planning,

c. providing direct one person control when unforseen anomalies arise.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

600 - General - All

RELATED SPECIFICATIONS

A813-1

TRADEOFF TITLE

A81-3 How far should we go in multitasking-especially a single CPU?

REQUIREMENTS/BACKGROUND

The process of assigning more than one function at a time to a CPU is known as multitasking. This study involves a tradeoff between accomplishing one function as quick as possible or running as many functions as possible within a longer period of time.

DESIGN APPROACHES/CHARACTERISTICS

There are two basic approaches:

a. Allow only one task at a time to be associated with a given CPU, and

b. Allow a sufficient number of tasks to be worked on simultaneously so that a maximum efficiency rate can be achieved with the CPU while all time lines are met.

ANALYSIS

Examination of the "average" GWC function has shown that as many as 2.19 may operate simultaneously and still complete within their expected wall times. It would therefore be a waste of CPU resource to have as little as 1 "average" function active in a system at a time.

The GWC network is not made up of "average" functions however, so the 2.19 figure cannot be applied without further study. This is where the simulation models come into play as a tool which may help to predict how much multitasking is reasonable.

SUMMARY/CONCLUSIONS

Multitasking should be strived for to the maximum extent that the individual functions and their time lines allow.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A311-8 through 9, A264-3, 4

TRADEOFF TITLE

A81-4 To what extent should functions be centralized as they are in the current operating system?

REQUIREMENTS/BACKGROUND

Centralization of functions is desirable because of the natural ability to schedule synchronous activities or at least those on the same time base. It is further desirable due to the centralization of software and obviating reading continuous processing software in and out of core. Centralization avoids the switching of resources such as external communications lines of consoles. Finally, components can be specially constructed to best adapt to the functions.

The disadvantage of centralizing functions is the requirement for a total backup, the inability to smooth out peaks and valleys in loading between various functions and the impact of growth and change on the system configuration (requiring a complete redesign).

DESIGN APPROACHES/CHARACTERISTICS

(See REQUIREMENTS/BACKGROUND)

ANALYSIS

Avoidance of maximum security within a processor or data base subsystem requires centralization for each security classification level. We recommend however that the software be written/changed to force a maximum amount of computation to be accomplished at the unclassified level where the computation is indeed unclassified and other overriding considerations are not present. Beyond that, the degree of required centralization becomes a function of the ability to allocate resources within a prespecified data base environment and the avoidance of additional cost due to added complexity in trying to generalize the application of resources. In general, we want to provide a batch processing system and have proposed a prioritized dynamic network queue along with roll-in/roll-out and job reallocation capabilities to accomplish our objective.

SUMMARY/CONCLUSIONS

The only two areas which are exceptions (to the extent that someone needs to feel the responsibility) are network control and master data base management. Network control has to be the central scheduler of jobs and therefore must be one resource which is identifiable. Other resources, however, have to sense whether or not he is doing this job properly and therefore taking over the job when required. The data base manager, we feel, has to respond quickly and we are not certain that going through the network scheduling loop would accomplish this job in a rapid enough manner and therefore have dedicated it to a single computer. Except for the jobs which have been centralized to different computers (e.g., array processors or comm processors) we feel the rest of the system should run on batch basis under the constraints of security.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A132-1, A813-2

TRADEOFF TITLE

A81-5 Should automatic scheduling be used or should the manual mode be continued?

REQUIREMENTS/BACKGROUND

On the surface, because of components required for reliability, there does not appear to be a great need for detailed scheduling. Not immediately apparent is that the ability to schedule determines the redundancy required to meet requirement reliability.

DESIGN APPROACHES/CHARACTERISTICS

We can either continue with manual scheduling or develop a Network Control concept which automates this function.

ANALYSIS

The ability to schedule to minimize waste is equivalent to keeping redundant resource to support peak load operations. The better the scheduler, the cheaper the system. Within current operations, there is approximately 43% wait time associated with computer runs. This can be reduced to say 10%; then about 1/3 of the total resource will not be required. A good scheduling program can be developed for 2 - 3 million dollars and resource that it may save amounts to 10 or 20 million dollars. The ability to schedule also reduces the need to centralize common functions. The noncentralization of functions results in more efficient system usage. The end result is again a savings in resource.

Another consideration is the switching of components to recover from malfunctions and/or distributed peak load conditions. In the environment of two-minute requirements, we do not feel the manual counterpart to the switching function would assure meeting the requirements. As a consequence, the automatic switching portion of the network scheduling function is mandatory.

SUMMARY/CONCLUSIONS

Under the previous system, the cost of a central network scheduler was not justified nor was the ability to solve the security problems associated with it. Under the conditions of design against a strict reliability requirement, the network scheduler is well justified.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

602 - General - All

RELATED SPECIFICATIONS

A813-1

TRADEOFF TITLE

A81-6 What is the tradeoff between one and two network control systems?

REQUIREMENTS/BACKGROUND

Precedence which dictates complete separation of normal and special access functions is not consistent with current design.

DESIGN APPROACHES/CHARACTERISTICS

A single network control function requires significant communications between the normal and special access areas. Two functions, however, obviate the ability to keep computation at the lowest level.

ANALYSIS

The decision to operate and compute at the security level of computation and data necessitates moving many special access time critical functions outside of the special access perimeter into the other computation components. The results are then sent back over the one-way communication channel to the special access computers where the results are used for computation. We feel that this interaction requires precise scheduling of resources and single point knowledge of what is to be accomplished. Since the network control interface is a control-only data line, it was felt that this function could take place within the special access perimeter providing information to the outside. This concept follows even further where computation done within the normal access perimeter has interaction with the consoles outside either perimeter.

SUMMARY/CONCLUSION

a. Two network control functions would still result in substantial communication between controllers or a great increase in resources.
b. There is no security risk to compromising special access data because of unclassified network control functions being performed and because of "control-only" concept of communications.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A813-2

TRADEOFF TITLE

A81-7 What is the tradeoff between the benefits of exact knowledge of task timing and the amount of resources needed to gather that knowledge?

REQUIREMENTS/BACKGROUND

Task scheduling requires decisions as to which tasks to start, which to terminate, and which to temporarily suspend. The information needed to make these decisions includes relative importance and a timeliness requirement for each task, and current progress toward completion of each active task. In the present GWC system, this is done through manual intervention by the computer operators using "checklists" which contain the necessary information. These checklists are prepared days in advance and are based on information gathered from previous program runs which is used to predict nominal running times and progress of programs. This method of scheduling places heavy responsibility on the operators, and requires that they be familiar with the functioning of each of the major programs. As the GWC system becomes larger and more complex, this method of scheduling will become increasingly inadequate and will eventually have to be abandoned. This will be due to the variety of configurations which may be established ad hoc, and the varying interference between tasks which contend for shared resources. It will become increasingly necessary to obtain and use knowledge of the current state of the system and progress of active tasks in performing the scheduling function.

DESIGN APPROACHES/CHARACTERISTICS

(See ANALYSIS)

ANALYSIS

To satisfy the requirement, each program which operates in the system must provide progress reports to its supervising executive. A standard method must be formulated for this report, which would presumably be conveyed to the executive via a subroutine call. The executive must maintain a table of the progress of each task within its jurisdiction. The network control program must be able to retrieve this information from any executive on

request, and associate it with data which it retains on each of the existent tasks of the system. The latter would include real time requirements for the task, and a nominal profile of progress against which the actual progress can be compared.

Network control must also have information regarding the status and use of dedicated and shared resources assigned to tasks. Dedicated resources would include both physical components (e.g., tape drives) and logical components (e.g., main memory sections, and auxiliary scratch storage), and the status of such should be dynamically recorded (i.e., assigned, reserved, or free). Utilization of shared resources should be maintained by hardware and/or software monitoring for busy/idle information which the scheduling function can use in determining where resource capacity is available for additional tasks. It should be maintained on an individual task basis if the scheduling function is expected to be able to reduce the load on certain resources to enable critical tasks which are running late with respect to their nominal profiles to be placed back on schedule.

These requirements can be satisfied on some of the large computers by including code in the executive to read out timers or clocks which have sufficient precision to permit measuring of processor and other resource assignments. If we assume that the load on processing for this function must not increase the running times of programs by more than 0.1%, and that an average of 100 microseconds is required to read out and record the time lapse for an executing task, the function should not be performed more often than 10 times per second. This rate is easily achievable for the GWC model programs which make relatively infrequent I/O demands for the amount of computation performed. Data base maintenance, reporting, and display programs may push this limit, but if timing does become a serious problem for some critical program, the period measurements could be suspended.

If the computer does not have a built-in clock or timer with sufficient resolution (e.g., on the order of a microsecond), it is recommended that an auxiliary addressable timer with the necessary resolution be obtained and attached to the computer. As a last resort, an independent probe could be

attached to the computer to measure CPU idle time (as indicated by a "wait" processor state). This is a less satisfactory approach since it does not provide processor utilization by task, and will still require acceptability by the executive or the network control function for read-out and interpretation either on an interrupt or sampling basis.

SUMMARY/CONCLUSIONS

A fairly complex analysis and feedback capability is required.

Each programming task will provide progress reports to its supervisor; this information is in turn provided to network control as a statistic.

There will be clocking of processor associated functions to provide statistics on system utilization.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A527-5, 8, A831-11

TRADEOFF TITLE

A81-8 What should be the depth of responsibility of the network controller to the scheduling of processors in a multi-processor configuration?

REQUIREMENTS/BACKGROUND

One of the advantages of a multi-processor is the ability of the executive to utilize both processors to a maximum advantage in a tightly coupled environment.

DESIGN APPROACHES/CHARACTERISTICS

The network controller can treat a multi-processor as two individual processors or as a unit.

ANALYSIS

The direct scheduling of each processor or even the prediction of expected job allocation by the Network Control function seems to be a waste of resource and an unnecessary function. There appears to be no cost or efficiency advantage to be gained.

SUMMARY/CONCLUSIONS

The network controller should schedule the multi-processor as a unit, but taking into account the increased capability in terms of its prediction algorithms. The Network Control function should never try to assess individual elements of a multi-processor running as a unit. Resource scheduling should never go below the level of that unit. The network control should, however, take into account when the two sides are operating as a unit uniprocessor or in the event of malfunction.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A813-11

TRADEOFF TITLE

A82-1 What are the advantages of maintaining the lowest security levels?

REQUIREMENTS/BACKGROUND

A tentative decision was made to maintain the lowest security level possible. This goal might result in added software costs involved in:

a. downgrading data or a system, or
b. communicating between systems of different security levels.

DESIGN APPROACHES/CHARACTERISTICS

a. Retain present procedure of permanent system security level, minimum automated security downgrade, and substantial manual downgrade.

b. Establish a method where both software and systems are maintained at the lowest level possible (and supported with the additional software to accomplish this).

ANALYSIS

Under the present system, far more computation is done above the classification security level required. This often results in a necessary manual downgrade of data resulting in security problems. At other times the downgrade is difficult if not impossible.

If data are kept at a low level, then the only data to be upgraded are those absolutely necessary. Several advantages result. Manpower is saved since the checking function is reduced to the absolutely required classified output. There will be far more computation accomplished at the unclassified level (probably more than 90%) resulting in a more efficient scheduling of resources and consequently fewer resources required to meet peak load requirements (as much as a whole processor may be saved).

The disadvantages are a more difficult scheduling problem and a more complex software design.

SUMMARY/CONCLUSIONS

We conclude that this step is a cost savings and well within the grasp of current data system design under the proposed configuration.

Software will be modularized and design will be accomplished to accommodate the capability to perform computation at the lowest security level possible consistent with modularity and network control efficiency.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

100 - Special Activities - All
200 - Command Control Systems - All
300 - Emergency War Order Support - All
500 - Space Environment Support - All

RELATED SPECIFICATIONS

A813-1

TRADEOFF TITLE

A82-2 Are more than two levels of protection required within the normal access perimeter?

REQUIREMENTS/BACKGROUND

In the current system mixed mode, computation is essentially accomplished at two levels: unclassified and others. This results in having to treat all classified computations as Top Secret until downgrade certification can be accomplished manually.

DESIGN APPROACHES/CHARACTERISTICS

The approaches are to accommodate two levels or all levels.

ANALYSIS

In the two-level approach, we are leaving the responsibility on the software to insure that a message marked Confidential going out over a data link really does not contain any Top Secret information. The only other alternative would be to treat the information as Top Secret throughout processing and then downgrade it prior to release, but this downgrade would have to be visual under the current security groundrules. We feel, therefore, that although the design problems are greater, we should go to a multi-level system. The impact of this decision would be great if we did not have a network scheduler and a rapid clean and switch capability which optimizes the time at which the system must be at a classified level when there was demand for such resource at a lower classified level. The problem for the network control function is only slightly worse than it would have been otherwise.

SUMMARY/CONCLUSIONS

We should accommodate within the design all levels and in fact provide for added compartmentalization if required.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

100 - Special Activities - All

200 - Command Control Systems - All

300 - Emergency War Order Support - All

500 - Space Environment Support - All

RELATED SPECIFICATIONS

A821-1

TRADEOFF TITLE

A82-3 Shall the design accommodate a future secure operating system?

REQUIREMENTS/BACKGROUND

The security approach identified in this design is almost entirely hardware and does have a mixed mode aspect in the routing of communications as well as requiring significant manpower for downgrade certification.

DESIGN APPROACHES/CHARACTERISTICS

We can minimize cost by not trying to produce a design which will be compatible with what we expect to be the final solution to mixed mode environment or we can investigate the current approaches and arrive at a system which is compatible but will impose additional cost to the data system.

ANALYSIS

There are two primary elements within the data system which must be isolated to insure mixed mode secure operations within a single processor environment: The first is an executive which cannot be compromised and the second is a data base manager which cannot be compromised. The eventual solution will be code which will probably be executed by an independent set of computer functions maintained in a separate protected memory and have no possibility of intervention from the outside world. Although there are some processors which have such capabilities, they have not been bought-off nor do they have the other characteristics which are required in our architectural design. We suspect that the hardware capability will not be a simple add-on feature no matter what computer we select, and that, in fact, a whole new hardware procurement must be accomplished to attain such features. Even with these features, there is no solution to the mixed mode environment of data coming in over the communication line so that solutions under those conditions are no better than the proposed architecture.

SUMMARY/CONCLUSIONS

We conclude that there is no advantage to pursuing a design to accommodate a secure operating system and, therefore, will not consider this in our design.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

100 - Special Activities - All
200 - Command Control Systems - All
300 - Emergency War Order Support - All
500 - Space Environment Support - All

RELATED SPECIFICATIONS

A821-14

TRADEOFF TITLE

A82-4 What performance measurement software is required?

REQUIREMENTS/BACKGROUND

Performance measurements become necessary when the system begins to show signs of strain in handling the applied workload. The purpose of such measurement is to determine where resources are not being effectively utilized, and hence where excess capacity may exist. In order to make use of data obtained by performance measurement, it is also necessary to correlate utilization with the workload.

DESIGN APPROACHES/CHARACTERISTICS

The idea of performance measurements closely ties in to a data gathering requirement discussed in the data storage area: collection of data base usage statistics.

ANALYSIS

The characteristics which should be monitored in performance measurement include:

a. frequency of retrieval from identifiable segments of data bases,

b. frequency of update of identifiable segments of data bases,

c. maximum and average backlogs of requests for access to data bases and/or data base storage units,

d. main memory sectional access via Monte Carlo methods, and

e. idle time fraction for central processors.

Measuring software should be incorporated as an integral part of the operating system, to be activated and deactivated either by programs (which may be clock driven) or by manual request. Thus, a function such as that provided by DMGOST in the present GWC system could gather statistics on data base usage for periods during which specific tasks are performed. In similar fashion,

request backlogs and memory references could be sampled and tallied for specific tasks or combinations of concurrent tasks. The measurement of idle time for processors could be handled via a hardware probe which records "wait" status of a processor and which can be queried by software. If it must be done entirely by software, it will be necessary to factor out the effect of the monitoring and recording software in order to determine the true processor utilization under normal operation.

Additional programs should be developed to process the data collected by the measuring software, and to prepare reports which indicate:

a. whether update or retrieval should be the principal factor in determining the organization of data bases,

b. which data bases should be associated or disassociated among the auxiliary storage units (e.g., disks) to minimize contention for resources among tasks,

c. which blocks of data or programs are referenced infrequently while in main memory, and hence are likely candidates for roll-in-roll-out,

d. where additional redundant paths for data transfer may be beneficial to overall performance, and

e. which combinations of concurrent tasks can most fully utilize the central processors.

SUMMARY/CONCLUSIONS

The data gathered by such measuring software can be used to modify the workload schedule for the system, the system configuration, the distribution of data among the auxiliary storage units, or the programs which are employed in performing GWC tasks.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A527-3 through 9

TRADEOFF TITLE

A83-1 How will phaseover from the '77 baseline to the new data system be accomplished?

REQUIREMENTS/BACKGROUND

Operations during phaseover cannot be interrupted, and there will be no additional space available, other than that specified for the final system. There will be certain functions in the current system which will eventually be deleted but must be kept operational while phaseover is accomplished.

DESIGN APPROACHES/CHARACTERISTICS

There seems to be only one option: that of performing the phaseover in very small increments, taking advantage of the flexibility of the new system and accomplishing this before the full load of new requirements is due.

ANALYSIS

The first step will be to develop a prototype system. This system will consist of one of each major component to be included in the final system. A development center will be established, preferably inside AFGWC if there is room. If no room is available at GWC, then the prototype system will be developed outside, probably at a contractor facility.

The communications system/terminal interface will be developed next. A duplicate system will be installed side-by-side with the present one and phased in through a trial run philosophy. The primary difference between the new system and the old system will be in the switching logic which will separate the incoming traffic into separate paths according to classification instead of all messages being routed directly into System I.

The next step is to provide new system components which are functionally the same as those in the old system. Each computer system within the old configuration will then be replaced, one computer at a time with the identical functions.

This is assumed to be possible since there will be an over-abundance of capability at the time of phaseover; however, there is the possibility that it will be necessary to procure certain required components for the purposes of phaseover and then deleting them again as soon as the system can be brought into operation.

Auxiliary functions which have no new system counterpart will be run on as few resources as possible. These will probably be located in the SX area. If this is so, a manual security downgrade function will be required during the phaseover.

Installation of a network control capability will be the next step. Until actual transfer of functions to the new network control, operations will continue to be scheduled in the current manner. During this period, a redistribution of classified functions must be accomplished. This will be one of the most difficult parts of the phaseover activity. This must begin to take place as soon as the new processors are brought into the system, and will require extensive planning. In addition, it may require some program modification to current software.

Final steps of the phaseover establish the automated work centers. When all of the consoles are connected, the system will be complete and provide complete automation.

SUMMARY/CONCLUSIONS

Phaseover can indeed be accomplished in a smooth non-interference manner by application of the basic procedure described above.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A831-1 through 12

TRADEOFF TITLE

A84-1 What is the requirement for system usage prediction/simulation?

REQUIREMENTS/BACKGROUND

Scheduler knowledge of future run requirements results in efficiency. The more efficiency the less resource is required to accommodate peak load. Prediction and simulation routines are costly in resource, expensive to build and sometimes are not very accurate in a dynamic system.

DESIGN APPROACHES/CHARACTERISTICS

(See REQUIREMENTS/BACKGROUND)

ANALYSIS

Prediction of system usage via simulation could reasonably be expected to yield useful results if performed on a gross level such as that depicted in the currently employed "checklists". However, the predictions would have to be rough, and would not include any significant effort at optimization, since the effort required to simulate in sufficient detail to consider impact of shared resources such as processors and data base access paths would be a costly process (in terms of computer resources utilized) and would likely not operate within real-time constraints (discrete simulation is notoriously time consuming).

However, any practical plan for utilizing resources to the fullest extent must depend upon some automated form of prediction, and a rough scheduling technique which depends upon previous experience with programs to be scheduled and the resources which must be dedicated or shared for their performance, would seem to be necessary. This scheduling should be done periodically, on an automatic basis, and manual requests for reruns with modified parameters should be permitted.

SUMMARY/CONCLUSIONS

We suggest the design of a prediction capability in the network control processor. The initial capability shall be the computation of resource utilization using a network analysis technique with "expected" run characteristics for scheduled functions and "expected" pad for unknown functions. Prediction should be to a point in the future where any present task being scheduled might conceivably be impacted.

The minimization of security upgrade and switching should be considered and conflicts against the status quo should be optimally resolved.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A813-7

TRADEOFF TITLE

A84-2 What simulation models should be incorporated?

REQUIREMENTS/BACKGROUND

Simulation models of a system as complicated as GWC's may be a useful tool in predicting and avoiding scheduling conflicts. The amount of sophistication employed by a simulation model will determine the amount of insight it will provide. Whether a simulation model should be used and the level of complexity necessary must be determined for the GWC case.

DESIGN APPROACHES/CHARACTERISTICS

(See ANALYSIS)

ANALYSIS

No simulation models should be suggested other than the scheduling prediction real time model described earlier. Operation of the system for a period of time (e.g., a week) can be viewed as a reasonable simulation of the system operation for a subsequent period. The insight which can be gained into future system operation by studying past operation would not be significantly increased by simulation unless a major perturbation in system operation is planned, and we are already attempting to evaluate this situation through simulation.

SUMMARY/CONCLUSIONS

No simulation models should be suggested other than the scheduling prediction real time model described earlier.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A813-7

TRADEOFF TITLE

A85-1 How are present software development techniques to be brought under a structured programming discipline (e.g., modularization, strict standards, level of abstraction)?

REQUIREMENTS/BACKGROUND

Structured programming reduces the number of programmers required for maintenance by lowering the error rate of software written under this discipline.

DESIGN APPROACHES/CHARACTERISTICS

The formal discipline of mandating that all future program coding be restricted to the use of structured programming provides an opportunity to improve productivity. Initial resistance to accepting such a discipline appears to be small. As programmers use structured forms and experience the advantages, the requirements for monitoring of program coding to assure adherence to the discipline should be minimal.

ANALYSIS

Independent sets of existing code which must remain intact in the new environment are treated as entities within a structured software system. The rules that are laid down for new coding and for the structuring of the code must then accept these entities under the constraints of the system, but on the other hand, internal to the entities there need not be compliance.

What are the elements of the structure that are applied against the programming task? The first is a hierarchical structure of function where each step in the hierarchy outlines a more detailed representation of the tasks that are performed by the software. These functions are stated independent of the control that must be imposed on the modules of the software system. They assume existence of data elements on the basis of need. They are, as much as possible, equal in terms of level of detail and size of job to be performed. Simultaneously with the functional hierarchy a data base structure is developed along with a philosophy for its use. Through an iterative process the data base

references in the final level of the hierarchy are made to correspond to the data base structure description. The next thing to be developed is a set of level of abstractions which dictate responsibility in terms of resource control and task control. Once the levels of responsibility have been defined and the resources of the system identified with levels and the packing order in terms of control are established, the executive control structure may be designed and imposed on the lowest level of task as described in the hierarchical structure.

It must be remembered that the elements of this functional representation as well as main elements of the data base description are distinct entities of present software. This will present an imbalance of levels and a lack of homogeneity and detail but it is still key to the integration of old and new software where a structure is superimposed.

The next essential step in the design process is the documenting of the system standards to be imposed on each of the programming areas. These are the sets of rules that the programmers must follow and the guidelines in terms of interface which are necessary in a structured environment. Two final documents are key in the design process and must be developed on a system-wide basis. The first is a compendium of mathematical equations used throughout the system presented not in programmer language but in strict mathematical notation. The second document is a user interface document which describes the human engineering aspects of the design at each operator position. This develops a philosophy of operation and a statement of task and considers the interface long before the code actually exists. All of these documents are living documents and should be updated as the design progresses. Now and only now can the actual software flowcharting and specification documentation begin. If the initial parts of this job have been done correctly, the development task will be much easier. The other parts of structured programming such as the chief programmer team concept, the training of programmers (see below), the methods of coding and the use of testing principles for checkout all are implemented independent of the fact that the system is one which augments a previous system as opposed to being completely new and independent programming.

Rotation of personnel, while complicating phaseover to chief programmer team organizations, can be used to facilitate the AFGWC transition to the other new methods discussed in that training in the new methods should be aimed at incoming new officers who are scheduled to be assigned to software development activities rather than on on-site personnel who have been trained in other methods or personnel slated for on-the-job training and maintenance, modification and software support assignments. With this approach all first time programmers at AFGWC will be indoctrinated within two years. This type of transitional training for phaseover to new methods avoids major perturbations of the training activity in that it provides for transition of programming courses from one small course teaching new methods of software development (presumably somewhat new and different techniques) into an integrated portion of the total AFGWC programmer training program two years later using appropriate training techniques which have had two years to mature.

SUMMARY/CONCLUSIONS

Present software can be brought under a structured programming capability in an orderly phaseover that should not lead to major problems for GWC.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A321-11, A323-2, A324-2

TRADEOFF TITLE

A85-2 How can maintenance of existing software be enhanced and new software be produced more effectively?

REQUIREMENTS/BACKGROUND

Although there are a large number of programming personnel at GWC, the program production and maintenance effort is a formidable one. In the future, expectations are that the need for more effective software production and management techniques will be essential. Two primary reasons are:

a. Indications are that although GWC is now operating at well below its authorized staffing level, the number of available skilled programmers will decrease, rather than increase. This will be primarily due to a dwindling supply of qualified Air Force personnel in these areas.

b. Ever-increasing numbers of new user requirements are being levied on GWC, requiring the generation and management of many new models, data handling routines, and numerous other programs. Attendant with this expansion of GWC responsibilities is the prospect of a much more sophisticated computer configuration, requiring more complex software for network control, security management, communications monitoring, and the like.

To keep pace with expected new requirements for GWC support, major improvements to software productivity are essential.

DESIGN APPROACHES/CHARACTERISTICS

In assessing potential methods for improvement of programmer productivity, SDC has given particular attention to three potentially fruitful areas:

a. Assessment of personnel performance factors,

b. Use of structured programming techniques, and

c. Use of interactive programming.

The conclusions drawn in these three areas are not dependent on a specific data system architecture, nor are there conflicts between these topics; that is, recommendations resulting from the analyses can be implemented individually or in total without conflict.

ANALYSIS

Studies and analysis involving personnel selection and motivation, structured programming techniques, and interactive programming are as follows:

a. Individual Performance Factors

The productivity of individual programmers is highly variable. A study conducted by SDC in 1959 showed that the ratio of worst to best productivity covered a very wide range for experienced programmers supposedly at the same skill level (see Table 8.1).

Table 8.1. Personnel Productivity

Performance On	Worst:Best
Debug Time Used	26:1
Computer Time Used	11:1
Coding Time	25:1
Code Size	5:1
Running Time	18:1

The most significant variable that can be manipulated to increase productivity is the improvement of this ratio. The gap between best and worst can be narrowed by selection of personnel, assignment of tasks, improvement measurement of productivity, training and individually tailored motivation. Narrowing of the range of productivity should also improve estimation of schedules.

The selection of personnel at GWC is constrained by standard Air Force duty assignment practices. However, a change to partial contract software development would enable some freedom in this area.

Individuals show considerable variability in their approach to work based on the interest they have in the subject matter and its relationship to other areas of interest. This variable cannot be ignored in any attempt to maintain high productivity, and some formal workable mechanism must exist for shifting of people between groups based on their desires. Programmers generally have a high intelligence level and become bored with routine. It is important to recognize the symptoms of this ennui and to be willing to pay the short-term price to maintain long-term efficiency. The author of one type of code (I/O routine, compiler, etc.) should not be doomed to repeat a similar effort continually for new projects because he is "best at it" and can "do it faster" than a new man.

The key to all improvement is an accurate and fair method of measuring productivity. The method has to contain room for a subjective assessment of the difficulty of the job, an estimate that should be agreed on by <u>both</u> the manager and the programmer <u>before</u> and <u>after</u> the job is done. The productivity should be broken down by categories such as those in Table 8.1, with agreement on the phase boundaries. Programmers should be ranked, and the ranking should be a prime factor in promotion. The ranking should be a closely guarded confidential list, but the individual programmer should be made aware of areas of exceptional performance, and of areas needing improvement, at periodic review times.

Training can be used to close the gap between best and worst by increasing the homogeneity of approach to software development, and by adding to the skills of inferior programmers. Most coders learn by imitating their superior during the early stages of their career and so the skill of a programmer is the result of a random, uncontrolled process. If he doesn't come in contact with a good example, he may never invent the methods on his own. Executive functions are often a mystery to applications programmers and tend to be a large bottleneck in degbugging. Programmers without operating system knowledge often debug by intuition and by inserting extra test code when enough

information is already present in a core dump. The problem is that they can't interpret it or trace the flow of control block pointers. Sometimes the lack of assembler programming hinders FORTRAN coders in reading a dump. In addition, programmers are often afraid to admit their ignorance by asking questions, especially when they have risen to senior status just by the passage of time.

Motivation of individuals in the GWC environment becomes the responsibility of the immediate supervisor. Due to the rigid promotion practices and salary levels of the Air Force, it isn't really feasible to motivate via accelerated promotion or monetary reward. Hence, the immediate supervisor must motivate via interpersonal relationships and informal management practices. Therefore, it is important to measure the success of management as well as the productivity of the programmer. It is also important to be flexible in allowing transfer between groups for the reasons of incompatibility between management and worker, without reprisal. The tradeoff that must be made is that some supervisors succeed by being very aggressive and may create short term antagonism. Evaluation of management success should not only be by those above, but by those below. The programmer should evaluate (anonymously if desired) his supervisor. Most importantly, action should be taken to evolve to the set of most effective managers.

The most important variable in productivity, the range of skill level, is also the most elusive to control. Composite design, structured programming and interactive development (discussed in succeeding sections) are better defined than the techniques of narrowing the range of productivity. All that has been attempted here is to delineate the variables that may be within the control of GWC management.

b. Chief Programmer Team, Composite Design, and Structured Programming

Composite design and structured programming disciplines offer productivity improvements of about 2 to 1* (and may be as high as 8 to 1) at little cost. The practice of structuring a program so that it can be easily understood and tested in a straightforward manner is not new. The goal of constructing software systems in well designed, easily modified modules has also been available for some time. The ingredient which has been added is that these methodologies were previously practiced as an art and have now been formally defined in such a way that they are now software engineering disciplines.

Rome Air Development Center is sponsoring a current study to verify the productivity enhancement due to use of the chief programmer team, composite design, and structured programming. At the completion of the contract, RADC expects to get the following products:

1) Rules and guidelines for writing structured programming software.
2) Formal programming techniques as a function of the language.
3) A study in data structuring methods in a structured programming environment.
4) Functional requirements for a Programming Support Library (PSL).
5) Software document standards.
6) Alternate methods of preparing program design specifications.
7) Requirements for software project management data collection and reporting.

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* The gain in programmer productivity is primarily in the code and debug phases of a programming project. The overall gain depends on the relative length of these phases compared the others, such as design and documentation.

8) Job descriptions for members of chief programmer team.

9) Estimating techniques on software resource requirements in a structured program environment.

10) Training course material in the use of structured programming technology.

This material should be available for use by GWC by mid-1975. Five volumes of the final set of 15 have already been published.

This technique of improving productivity, shortening schedules, and lowering error rates is receiving the attention of the entire industry. Information on it is abundant, in journals and from those who are transitioning to it. It is the clear direction of the industry, and represents a low risk, low cost way for GWC to improve software development. The lower error rates will also decrease the level of effort for maintenance of code; another attractive feature for GWC.

c. Interactive Programming

In addition to the formal structure of composite design, etc., interactive software development offers productivity gains. The gains here are somewhat offset by additional computer costs. The size of the gain appears to be about 2 to 1*, (and may be as large as 6 to 1) in addition to the gain due to structured programming.

Interactive programming has been available for many years without success. It has blossomed now primarily due to the decrease in hardware cost and the increase in total system reliability.

* The gain in programmer productivity is primarily in the code and debug phases of a programming project. The overall gain depends on the relative length of these phases compared the others, such as design and documentation.

There are three levels of interactive programming: debugging interpreters/compilers, on-line execution of small programs, and on-line creation of large batch programs. The benefit derived from each of these functions can be evaluated separately. Each installation strikes a different balance in usage and its responsiveness to these functions. The software to support terminals and provide executive interfaces is vendor supplied and maintained. Examples are IBM's Time Sharing Option (TSO) and Univac's Conversational Time Sharing (CTS/1100).

SUMMARY/CONCLUSIONS

Three major areas for consideration in increasing programmer productivity are as follows:

a. Individual performance factors Wide variations in personnel capabilities are often found at a given skill level. At GWC, this can be alleviated by well planned selection of personnel, periodic assignment to more rewarding tasks, improved measurement of productivity, training, and individually tailored motivation.

b. Chief programmer team, composite design, and structured programming This involves the practice of structuring a program so that it can be easily understood and tested in a straightforward manner. Rome Air Development Center is sponsoring a study to verify the productivity enhancement due to these techniques, which represent low risk and low cost methods of improving software development productivity at GWC.

c. Interactive programming Real time interactive techniques offer distinct possibilities to accelerate GWC software production. Program assembly, routine debugging, and system tests can all be accomplished in streamlined fashion from interactive consoles. With terminal costs decreasing and manpower costs increasing, this option becomes an even more viable technique to increase GWC software productivity and maintenance.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

602 - General - Manpower Productivity

RELATED SPECIFICATIONS

A528-1 through 8, A52-5

TRADEOFF TITLE

A86-1 To what extent should hardware/software self diagnosis be provided?

REQUIREMENTS/BACKGROUND

Hardware and software reliability requirements demand that the possibility of self-diagnosis be investigated. If a problem has arisen or indications exist that it might, proper action by the hardware/software may keep the reliability standards from being violated.

DESIGN APPROACHES/CHARACTERISTICS

(See ANALYSIS)

ANALYSIS

Reliability requirements at AFGWC dictate that hardware/software problems be corrected promptly. Self-diagnosis capabilities provided with the hardware which protect against highly probable problems at a reasonable overhead need no justification. However, in some cases hardware reliability self checking overkill is self defeating in that it creates an overhead or causes additional costs not merited by the protection it provides. Software self-diagnosis software can also be self-defeating if it unduly complicates software checkout, creates a high run time overhead, or increases software development costs beyond costs merited by the protection provided. Software statements which are typical of well justified software diagnosis statements include: statements which check the reasonableness of data which has been calculated such as a check for a negative attitude; and statements which prevent entry into program blocks based on unexpected values such as a check for a northern hemisphere code value and a check for a southern hemisphere code value as opposed to code which assumes southern hemisphere if the code value received did not designate northern hemisphere. No hardware diagnostics logic should be added unless it has been proven in the field. No software diagnostic techniques should be included unless they have been proven to be free of problems and of value in keeping the system in reliable operation.

SUMMARY/CONCLUSIONS

Hardware/software capabilities for self-diagnosis should be provided only to the extent that they can isolate problems which are likely to occur, and that the cost involved is small relative to the reliability gained.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

RELATED SPECIFICATIONS

A321-1, A512-6

9.0 FACILITIES

TRADEOFF TITLE

A93-1 Can the hardware layout of future computer configurations conform to the GWC facility space available?

REQUIREMENTS/BACKGROUND

The current facilities being used at AFGWC will continue to be used throughout the time frame 1977 through 1982. Although there are plans for additions to provide additional office space for AFGWC, the current facilities will continue to be utilized for sizing the computer systems. The baseline 1977 systems will exist in AFGWC as follows: Systems I, II, III, and IV will be on the main floor while systems V and VI plus the data base computer will be on the lower floor. Thus, there are a large number of rooms which have already been structured to house computer systems.

DESIGN APPROACHES/CHARACTERISTICS

The total facility floor space available at AFGWC is illustrated in Figures 5 and 6. The actual hardware layout using this space has considered the following groundrules:

a. Allocate the rooms according to the perimeters required for security classification purposes; these perimeters are designated Normal Access, Variable Access, and Special Access.

b. Forecaster and programmer console placements are all approximate and can be relocated to nearby areas without complication.

c. Provide support computers for and the automated work centers.

d. Isolate the printers where possible to help lower the noise levels.

e. Provide adequate space for network control and the operations centers.

f. Use Option C, Table 10.11 (5-3, 5RP and 5-50RP array processors) for the hardware components.

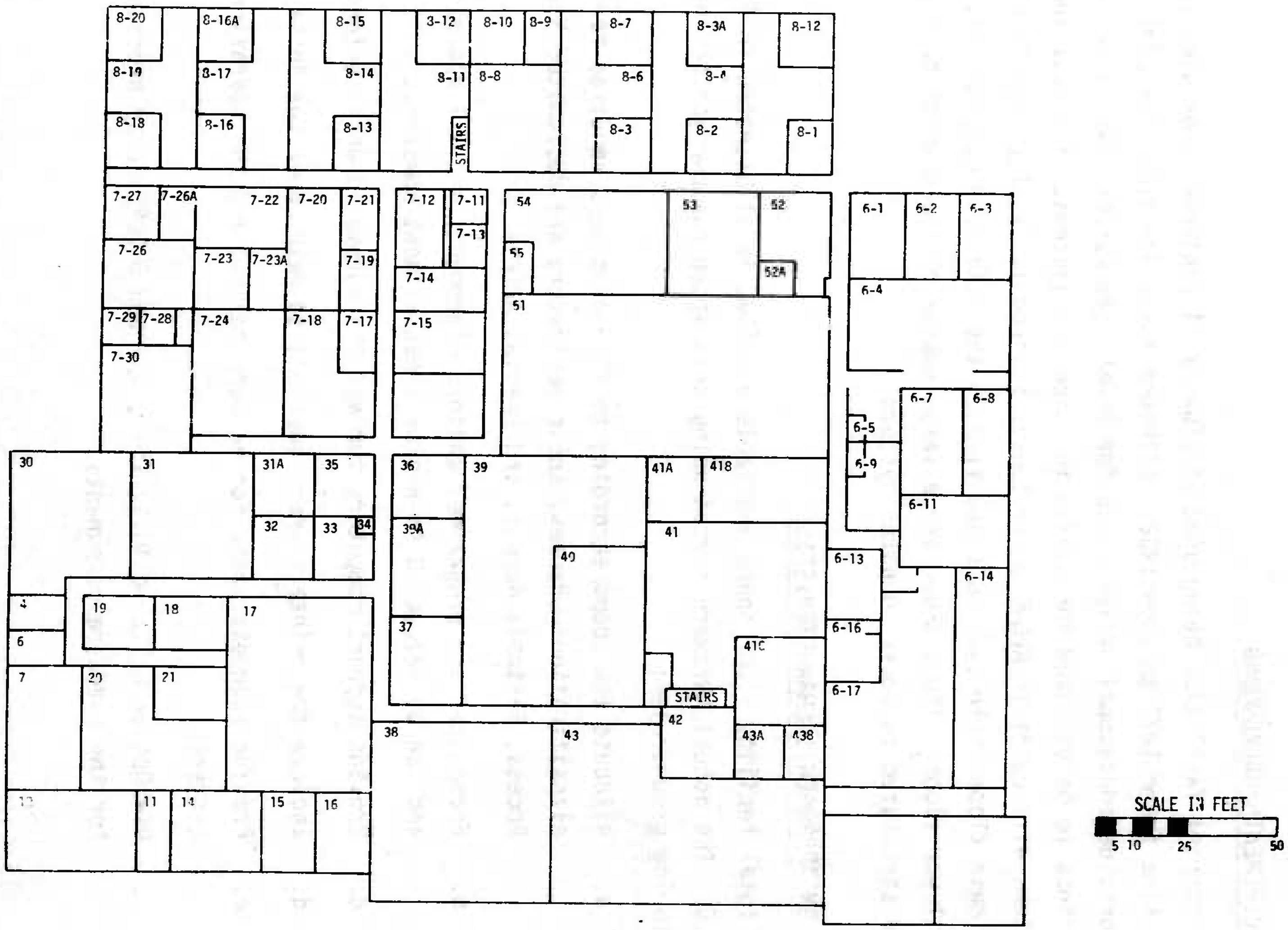


Figure 5. GWC Main Floor Equipment Areas

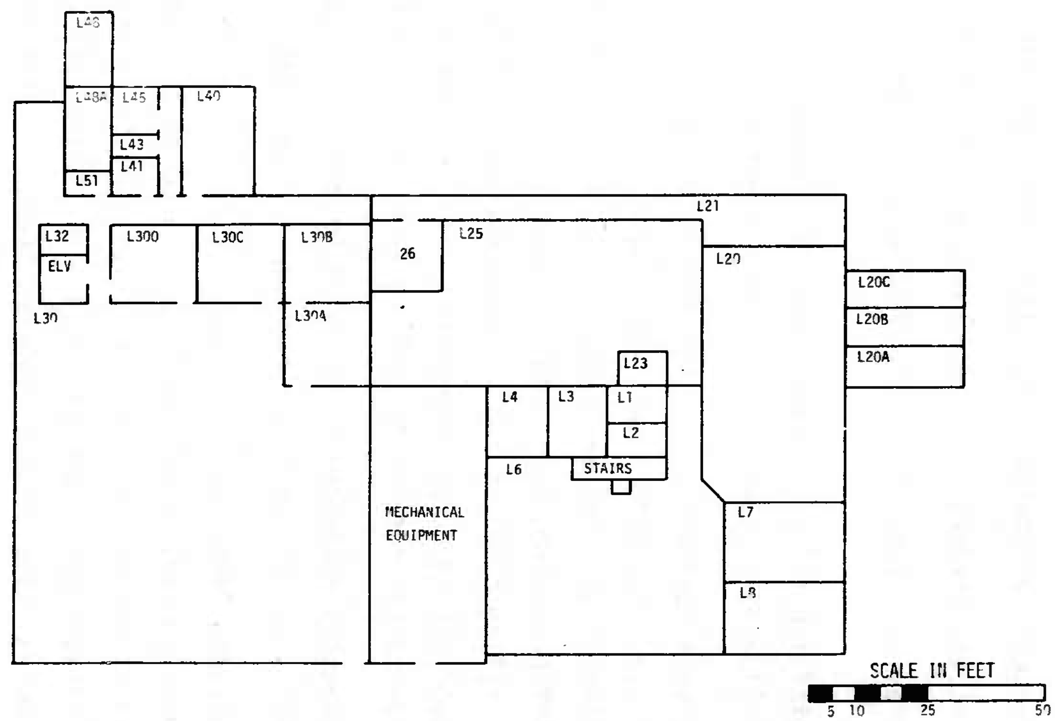


Figure 6. GWC Lower Floor Equipment Areas

ANALYSIS

The following room allocations have been determined to be the most effective utilization of the available space:

a. Normal-acess perimeter: rooms 17 and 20 on the main floor and room L-30 on the lower floor.

b. Variable-access perimeter: room 38 on the main floor.

c. Special-access perimeter: room 43 on the main floor.

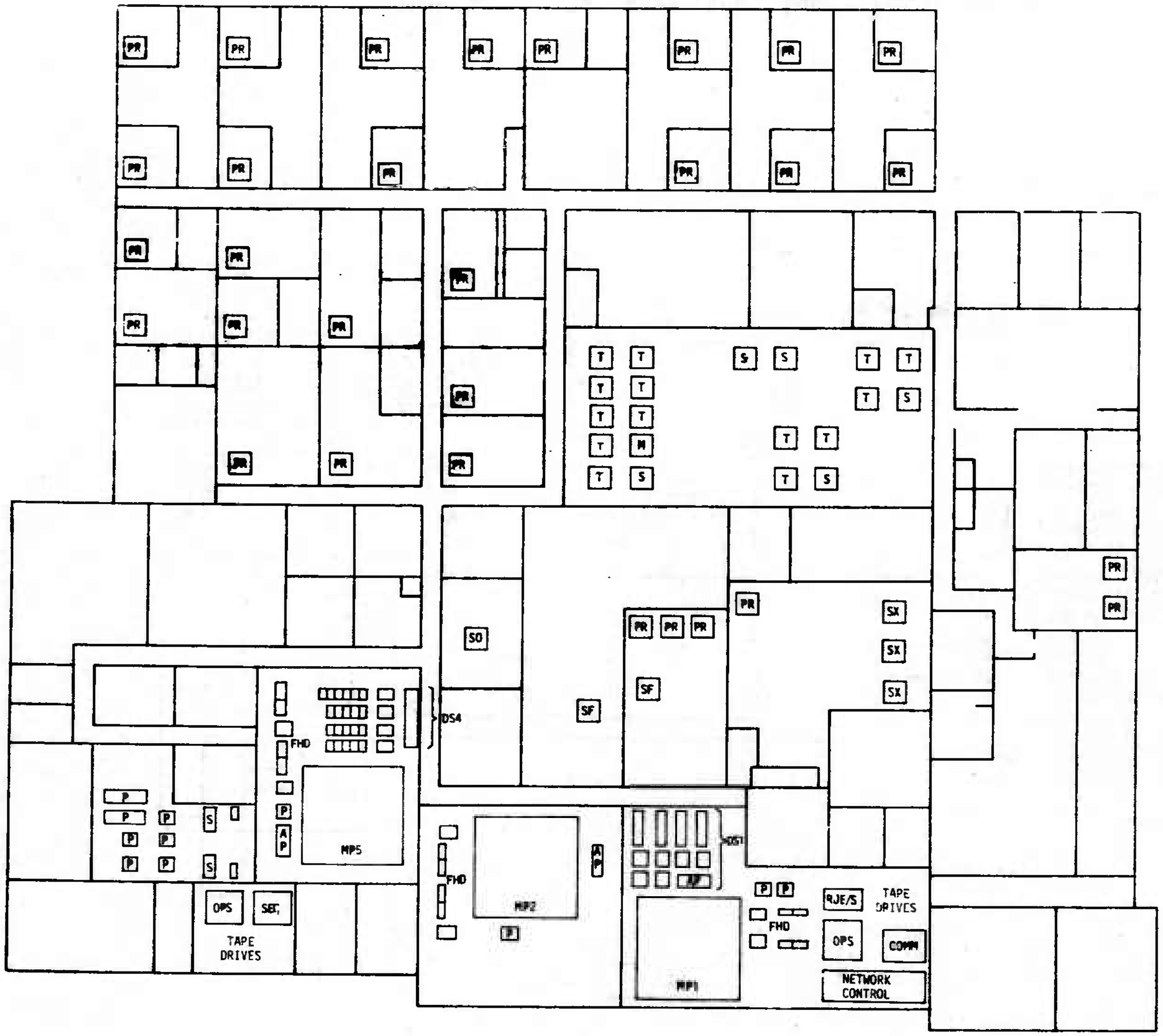
d. Tape libraries: rooms 15, 16, and 43-A on the main floor.

In addition to satisfying all the ground rules, the proposed hardware layout will include the following features (see Figures 7 and 8):

a. Normal-Access Perimeter - In the room on the main floor where the printers are located there will be an area designated for manual disposition of the printer output. Also on the main floor will be 1-3.5RP processor, tape handling equipment and the central data base consisting of disks and the mass storage facility. On the lower floor the two 3.5RP processors will be closely located so that it would be possible to combine them into a 4 x 4 configuration.

b. Variable-Access Perimeter - This will be totally located on the main floor with all necessary equipment in one room.

c. Special-Access Perimeter - This will be totally on the main floor. The network control console will be located in this area because it must have access to all levels of classification. Because of the classification associated with this area, there will be printers as well as manual tape drives. Support computers associated with this perimeter will also be located in this area.



ABBREVIATIONS

AP - ARRAY PROCESSOR
COMM - COMMUNICATIONS CONSOLE
DS - DISK SYSTEM
FHD - FIXED HEAD DISK
M - MILITARY WEATHER ADVISORY CONSOLE
MP - MAIN PROCESSOR
OPS - OPERATIONS CONSOLE
P - PRINTER
PR - PROGRAMMER CONSOLE
RJE/S - REMOTE JOB ENTRY/SECURITY CONSOLE
S - SYNOPTICIAN/HWD CONSOLE
SA - SATELLITE DATA
SEC - SECURITY CONSOLE
SF - SESS CONSOLE
SO - SPECIAL OPERATIONS CONSOLE
T - TAF/METWATCH CONSOLE

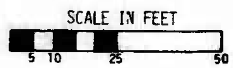


Figure 7. GWC Hardware Layout Main Floor

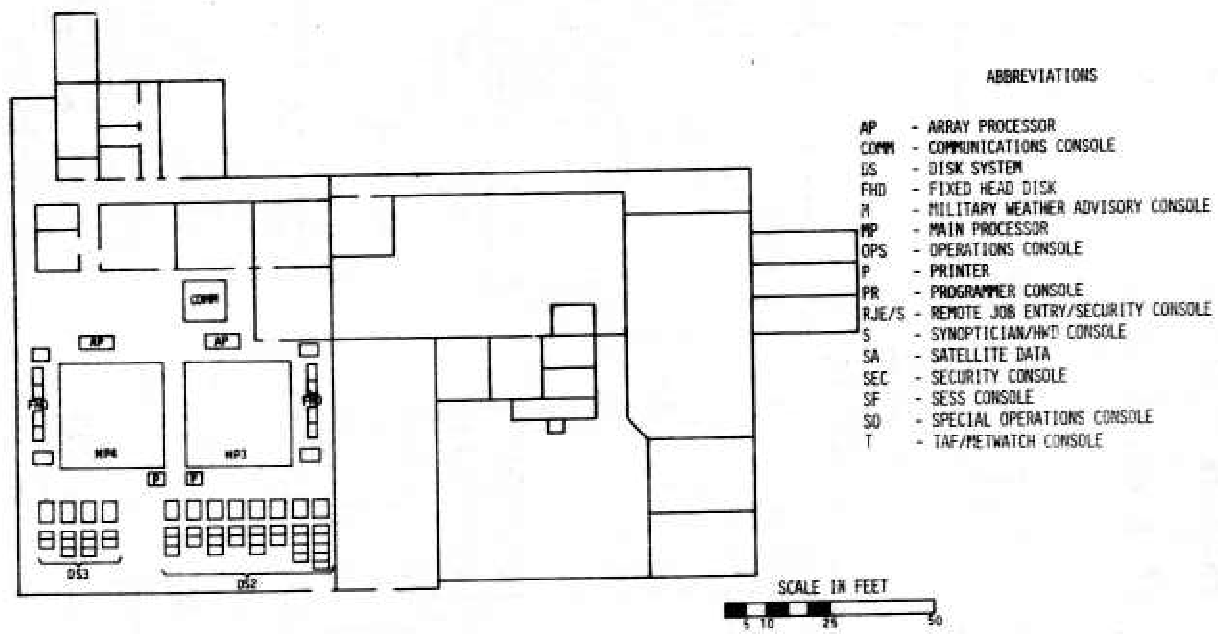


Figure 8. GWC Hardware Layout Lower Floor

SUMMARY/CONCLUSIONS

Adequate GWC facility space is available to house the hardware and allow for phaseover involved in a typical future computer configuration.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

601 - General - Growth

10.0 COSTING

TRADEOFF TITLE

AC1-1 What cost is associated with the hardware and software in the proposed architecture?*

REQUIREMENTS/BACKGROUND

This section summarizes the rationales that have been applied to the compilation of hardware and software cost elements of candidate GWC data system architectures. These costs reflect total (worst case) GWC requirements, in that all user requirements, prospective models, and general system requirements have been considered in developing these figures. Cost elements essentially reflect capabilities that will be required in 1982; that is, a growth in required capabilities will be required over the 1977-82 time period, with emphasis in the 1977-1980 time frame, culminating in maximum required data system capability in 1982.

DESIGN APPROACHES/CHARACTERISTICS

The costing approach has been segregated into hardware and software acquisition costs, as follows:

A. Hardware

Five alternate hardware configurations were costed, with hardware components categorized into the following areas:

1. Processor subsystems (including main memories)
2. Auxiliary storage subsystems (disk equipment)
3. Centralized data base options
4. Work center subsystems and associated support processors
5. Satellite-unique processor options
6. Miscellaneous peripherals and components

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*These costs are current as of the Task 3/4 briefing. Final configuration costs appear in volume 7 of the Final Report, section 3.0.

Purchase costs in most cases were obtained from vendor-supplied information, and included sources such as vendor briefings and consultations, manufacturer's literature, and SDC's assessments of current and projected component costs for representative devices. Except as noted, monthly rentals were obtained by using a 40-month amortization assumption; i.e., purchase costs were generally divided by 40 to determine monthly rental charges. Monthly maintenance was generally obtained by:

monthly maintenance = purchase cost x 0.002 x 5

where 0.002 is a typical ratio for 8-hour maintenance, and a factor of 5 is used to provide 7-day-a-week - 24-hour-a-day coverage.

B. Software

Software development costs were obtained by categorizing software into the following areas:

1. Model development
2. Satellite processing
3. Major miscellaneous areas

Model sizing was based primarily on estimates provided by the Studies and Analysis Branch of GWC, as augmented by information obtained from other GWC organizations (primarily DO) and from SAMSO. Satellite processing sizing was obtained from the Data Acquisition and Processing Branch and from SAMSO personnel, while estimates for other areas were generated by various GWC organizations (where new user requirements could be well defined) and by SDC (for new capability areas, such as data system management and network control).

Associated dollar costs in 1975 dollars were based on a classification of these requirements for new code into major, moderate, and medium-to-low complexity efforts, and applying appropriate dollar-per-instruction costs and other pertinent factors. A summary of these assumptions appears in Table 10.1.

Conversion costs for existing software to run on new machines will vary considerably, depending on the processor configuration. Associated assumptions are as follows:

Table 12. New Software Development Cost Assumptions

- Instruction costs --

  Major Developments:

  Contractor Cost - $30/Instruction
  Air Force Cost - $20/Instruction

  Moderate Difficulty:

  Contractor Cost - $20/Instruction
  Air Force Cost - $10/Instruction

  Medium-to-Low Difficulty:

  Contractor Cost - $12/Instruction
  Air Force Cost - $ 7/Instruction

  Including -
  Program Design
  Program Coding
  Parameter Testing
  System Validation
  Documentation

- 50% of total effort performed by contractor, 50% of total effort performed by Air Force.

- Hardware-compatible higher order language used extensively - assembly level language(s) used for control programs and special applications.

- Program coding includes interactive and structured programming techniques for all but major development efforts.

1. <u>Option A (Eight 12RP main processors)</u>

   a. UNIVAC cannot respond in this processor range, requiring extensive software conversion costs.

   b. Mixed mode security will not be required in the 3.5RP machines; therefore, there should be no inclusion of the cost of converting RTOS. The restructuring of the data base will require a replacement of the machine language data base routines after 1978. Hence, no conversion costs are included for any machine language code.

   c. Non-UNIVAC 12RP main processors would not be available until 1978 for support of requirements. This was based on the following conditions:

      - No competitive procurement could begin until after completion of the study (approximately March 1976).
      - A procurement would require about a year, bringing the time table up to early 1977.
      - The lead time for main processors is about 6 months to 1 year, which results in an availability of hardware in January 1978.

   Requirements supported prior to 1978 would have to be coded for UNIVAC computers and converted.

   d. Conversion of FORTRAN code from one machine to another is typically 30% recode, 60% modify, 10% no change.

   e. The existing system today has about 1 million lines of FORTRAN, or about 5×10^6 instructions. About 20% will be replaced by future code, leaving 4×10^6 to be converted. Prior to 1978, approximately 170,000 new instructions will be written in the computation area alone. If this is about 80% of the total of new instructions, the number of instructions that must be converted is $4 \times 10^6 + (170{,}000 \div 0.8) = 4.2 \times 10^6$ instructions.

2. Option B (a mixture of 3.5RP and 12RP main processors)

No costs for conversion will be incurred because SDC assumes the Air Force could retain UNIVAC for the 3.5RP machines, and that the models requiring 12RP capacity would not be implemented until after 1978, when they could be tailored to the 12RP machines. The cost of this new implementation is estimated as part of new software development.

3. Options C, D, and E (3.5RP main processors with array processors rated at 50RP, 60RP & 95RP, respectively)

A mixture of 3.5RP main processors and 50 RP array processors (option C) would require main processor interface software, plus analysis of algorithms for vectorization of processing. (No interface software would be required in Options D or E.)

Vectorization software estimates were based on Lawrence Livermore Labs' experience with the CDC Star Computer (see Special-Purpose Hardware foldout in the Task 2 briefing). The interfacing software was estimated by SDC to be complex machine language code, but may be supplied (and not cost any additional money) if the array processor and the main processor are from the same vendor.

ANALYSIS

A. Hardware Costs

The costs for processor subsystems and main memories vary considerably between configuration options. Estimated dollar costs for the various classes of these components are:

PROCESSOR CLASS	PURCHASE COST PER UNIT	TYPICAL UNIT
3.5RP	$ 7.0 x 10^6	UNIVAC 1100/40 2 x 2, IBM 370/168
12RP (full capability)	$10.5 x 10^6	IBM 370/195, CDC CYBER 76
12RP (reduced capability)	$ 8.5 x 10^6	IBM 370/195, CDC CYBER 76
50RP	$ 0.5 x 10^6	PROTEUS, UNIVAC Seismic Array Processor
60RP	$15.0 x 10^6	STAR-100, CRAY-1
95RP	$ 2.0 x 10^6	PEPE, STARAN

A summary of the main processor and array processor costs associated with the five options initially selected is shown in Table 10.2.

Costs for most of the remaining classes of hardware components will be essentially independent of the selected processor subsystem configuration. (One exception is auxiliary storage, where the number, types, and capacities of disk units and controllers will vary as a function of the type and number of processor subsystems.) Summaries of hardware component costs for auxiliary storage, centralized data base options, and other categories of components are presented in Tables 10.3 through 10.7.

Table 13. Processor Subsystem/Main Memory Costs

OPTION	3.5RPs	12RPs (full capability)	12RPs (red. capability)	50RPs	60RPs	95RPs	Net Purchase Cost ($\$ \times 10^6$)	Monthly Rental Cost ($\$ \times 10^6$)	Monthly Maint. Cost ($\$ \times 10^6$)
A. 12RPs		3	5				74.0	1.85	0.74
B. 3.5RPs and 12RPs	5		6				86.0	2.15	0.86
C. 3.5RPs and 50RPs	5			5			37.5	0.94	0.38
D. 3.5RPs and 60RPs	5				6		125.0	3.13	1.25
E. 3.5RPs and 95RPs	5					3	41.0	1.03	0.41

Table 14. Auxilliary STorage Costs

STORAGE CATEGORY	PROTOTYPE	NO. OF DISK UNITS	TOTAL DISK COST ($\$X10^6$)	NO. OF DISK CONT.	TOTAL DISK CONT. COST ($\$X10^6$)	TOTAL PURCHASE COST ($\$X10^6$)	MONTHLY RENTAL COST ($\$X10^6$)	MONTHLY MAINT. COST ($\$X10^6$)
Bulk	UNIVAC8433	23	0.897	6	0.612	1.509	0.038	0.015
Satellite	UNIVAC8440	13	0.776	2	0.176	0.952	0.024	0.010
Fixed Head	UNIVAC8405	20	1.540	10	1.060	2.600	0.065	0.026
Combination	IBM3340	63	2.457	16	1.088	3.545	0.089	0.036
Support Interdata ($40X10^6$bytes)	($40X10^6$bytes)	8	0.056	2	0.036	0.092	0.002	0.001
			5.726		2.972	8.698	0.218	0.088

Table 15. Centralized Data Base Option Costs

COMPONENT	QUANTITY	PURCHASE COST ($ x 10^3)	MONTHLY RENTAL COST ($ x 10^3)	MONTHLY MAINT. COST ($ x 10^3)	
IBM 3850 B1*** Archival Storage	1	676	16.90	6.76	any combination of these three independent options may be implemented
CALCOMP Automated Tape Library	1	360	9.00	3.60	
STARAN Associative Processors	2	1300	16.25*	6.50**	
		2336	42.15	16.86	

*using 80-month amortization factor

**using a maintenance ratio of 0.001

***including disk-to-mass storage facility adapters (this option has been selected for the final architecture configuration - the other data base options have been discarded).

Table 16. Work Center Subsystem Costs

COMPONENT	QUANTITY	PURCHASE COST ($ x 10^3)	MONTHLY RENTAL COST ($ x 10^3)	MONTHLY MAINT. COST ($ x 10^3)
Vector CRT	17	60	1.50	0.60
High Resolution CRT	22	1100	27.50	1.10
Color CRT	17	85	2.13	0.85
Microfilm	2	130	3.25	1.30
Digitizing Tables	6	27	0.68	0.27
Interactive Term (ANK + CRT)	31 + 30	186	4.65	1.86
PDP 11/70 Class Interface Processor	7	2100	52.50	21.00
Bare Support Processor	31	310	7.75	3.10
Plotter	10	150	3.75	1.50
Printers				
100 lpm	6	90	2.25	0.90
1000 lpm	5	280	7.00	2.80
2000 lpm	5	435	10.88	4.35
11000 lpm	2	620	15.50	6.20
Floppy disk reader	4	32	0.80	0.32
Remote Cabling		250		
TOTALS		$5855	$140.14	$ 46.15

Table 17. Satellite Data Processing Option Costs

COMPONENT	QUANTITY	PURCHASE COST ($ x 10^3)	MONTHLY RENTAL COST ($ x 10^3)	MONTHLY MAINT. COST ($ x 10^3)	
PROTEUS Processors	2	1000	25	10	mutually exclusive options
PDP 11/70 * Interface Processor	4	1200	30	12	

* This option selected for the final architecture configuration.

Table 18. Miscellaneous Peripheral Component Costs

COMPONENT	QUANTITY	PURCHASE COST ($ X 10^3)	MONTHLY RENTAL COST ($ X 10^3)	MONTHLY MAINT. COST ($ X 10^3)
CARD RDR/PUNCH	4	150	4	1.5
TAPE DRIVES & CONTROLLERS	14	910	23	9.1
SYMBIONT-TYPE PROCESSORS (13K BYTES)	2	410	10	4.1
AUTHENTICATION DEVICES (CRYPTO CHIPS)	54*	350	-	-
SWITCHES	20	200	5	2.0
TOTALS		2020	42	16.7

* 14 - 1 way, 40 - 2 way

B. Software Costs

Details regarding software sizing are presented as follows:

1. Analysis and forecast models

   Based largely on information supplied by Studies and Analysis personnel, program size estimates and related comments for 38 defined model capabilities appear in Table 10.8. Assuming that 20% of the total constitutes machine instructions, this results in 495K instructions of executable code.

2. Satellite Processing

   These figures have been derived as follows:

   a. DMSP, TIROS Primary Data: 150K instructions

      Based on 35K new code for gridding and mapping DMSP fine data and 115K to process TIROS smooth data (36K for online program plus 94K for a gridder program, less 15K for reusable code from DMSP).

   b. GOES Primary Data: 35K instructions

      Based on estimate supplied by GWC (Lt. Col. Coburn).

   c. TIROS Secondary Data: 15K instructions

      Based on 5K instructions for each of three unique secondary sensors.

   d. GOES Secondary Data: 15K instructions

      Based on 5K instructions for each of three unique secondary sensors.

3. Major Miscellaneous Areas

   a. Product Request Processing: 130K instructions

      Based on 30K of new code for enhanced CFP system, 55K instructions for CFLOS extraction, and 45K to support Minuteman.

Table 19. Model Sizing

Model No.	YR	Title	Estimated Program Size: Analysis	Estimated Program Size: Forecast	Comments
1	77	Tropical Prediction Model based on Spherical Harmonics		75K	
2		Primitive Equation Window Model		210K	
3		Total Electron Count Model		50K	
4		Ionospheric Ray Tracing Model		75K	
5		Conjugate Aurora Program			White papered
6		NOAA Ionospheric Scintillation Model			White papered
7		Cloud Prognoses Model		210K	Same features as No. 2
8		Objective HWD Model		54K	Largest of 4 possible methods (others = 51K)
9		Terminal Forecast Model		180K	(45K = largest of 4 absolutes)
10		Global Analysis Model	65K		
11	78	Advanced METSAT Data Incorporation	90K	80K	(80K+45K+45K)-although 45K being done by outside contractor
12		Incorporation of some VHR and WHR Satellite Data into 3DNEPH	70K		

Table 19. (Cont'd)

Model No.	YR	Title	Estimated Program Size: Analysis	Estimated Program Size: Forecast	Comments
13	78	Advanced Global Atmospheric Prediction Model		140K	
14		Cloud Free Line-of-Sight		260K	
15		Clear Line-of-Sight			Included in No. 14
16		Statistical Polar Ionospheric Propagation Model		50K	
17	79	Incorporation of most VHR and WHR Data into 3DNEPH	60K		
18		Extraction of Field of Motion Data from GOES		80K	Based on 366K IBM bytes
19		Satellite Data Compression			White papered
20		Statistical I/F between Mesoscale Dynamic Model and Forecaster			White papered
21	80	Ceiling and Visibility Forecast PSIs			White papered
22		Incorporation of Satellite-Derived Liquid Water into Data Base			White papered
23		Improved TEC Model		100K	
24		Improved F-Region, Storm Model		50K	
25		Clear Line-of-Sight for IR			Included with No. 14

(Model 25 will include capabilities of Models 14 and 15; net size of Model 25 will remain at 260K, due to addition, deletion, and recombination of various elements of code.)

Table 19. (Con't)

Model No.	YR	Title	Estimated Program Size Analysis	Estimated Program Size Forecast	Comments
26	80	PE Window Model for High-Resolution Short-Range forecasts at Low Latitudes		210K	PE Window Model (same characteristics as ZOOM Model)
27	81	Variational Global Analysis Model	140K		
28		Satellite Sensor Simulation Model			White papered
29		Ceiling, Visibility Forecast PSIs for Locations without Observations			White papered
30		Clear Line-of-Sight for Microwave			White papered
31		Capability to Accept Compacted Output from Digital Radar			White papered
32	82	Dynamically Coupled Global Cloud Forecast Model			White papered (included in APM)
33		Liquid Water Prediction			White papered (included in APM)
34		Improved Ionospheric Magnetospheric Model		125K	
35		Forecast PSIs for Severe Weather			White papered
36	83	MOS for Liquid Water Prediction			White papered (post 78)
37		Incorporation of Radiation Physics Module into Global Prediction Model			In 78 Model
38	82	Neutral Density Model		100K	Assumed--No Data Available
			425K	2049K	2474K

b. <u>ETAC, Carswell Backup: 10K instructions</u>

Based on Lt. Col. Coburn's estimate of 5350 lines of object code to support six areas now supported by ETAC on their SPECTRA 70/45 and IBM 360/44 machines, plus SDC's estimate of 5K of new instructions to provide the formatting and switching functions performed by Carswell. This latter 5K figure is based on the following: Carswell now has two 1108s with a total capacity of 130K words. Assuming 25% is allocated to operating system use, this leaves about 100K words available. Assuming 20% of these are instructions, this results in 20K instructions. Of this figure, it is assumed that only 25% is for unique code that must be implemented at GWC to support Carswell customers, for a net of 5K.

c. <u>Communications Support: 50K instructions</u>

Based on the assumption that about 75% of the RTOS I-bank total of 31.7K (25K) can be recoded, and that about 25K of additional instructions will be required for accomplishing the new security determination, decoding, and routing requirements of the proposed system.

d. <u>Data System Management: 80K instructions</u>

This is based on SDC's assessment of the code required in the support computers and main processors to support quality control, computer operations, maintenance, security monitoring, and special operations functions, as well as code for data system performance measurement.

e. <u>Network Control: 50K instructions</u>

This is based on code required to support this function in the main processor, plus some associated code in a system support processor. Network control computations include, among other capabilities, routines for system usage prediction simulation.

f. <u>Programmer Support: 20K instructions</u>

This figure involves the estimated support for the software development, remote job entry, and studies and analysis console functions.

g. <u>Interface Processors to Support Forecaster Consoles: 100K instructions</u>

This is based on support to the display and routing options that will be available to a variety of types of Forecaster consoles, distributed among 24 different consoles and two interface processors. Estimates have considered the availability of vendor-supplied software and the possibilities for hardware-driven displays, as well as the requirements for new software to provide new requirements.

A summary of the new classes of programs that must be so developed appears in Table 10.9. Note that over one million instructions of new code is assumed to be required to support model requirements, user requirements, and the enhanced automation features that will be obtained in these new architectures.

To provide a cost estimate for this new development, these programs have been categorized as to expected level of difficulty in order to apply cost ground rules. The results of this categorization, along with the results of applying costing algorithms described earlier, appear in Table 10.10. It thus appears that for the estimated program requirements, a 50-50 mix of contractor and Air Force programming skills could conceivably generate this 10^6 words of new code for a cost on the order of $\$20 \times 10^6$.

Table 20. Required Program Development Summary

Model Development		
Analysis Models	- 85K Instructions	495K Instructions
Forecast Models	- 410K Instructions	
Satellite Processing		
DMSP, TIROS Primary Data	- 150K Instructions	215K Instructions
GOES Primary Data	- 35K Instructions	
TIROS Secondary Data	- 15K Instructions	
GOES Secondary Data	- 15K Instructions	
Major Miscellaneous Areas		
Product Request Processing	- 130K Instructions	440K Instructions
ETAC, Carswell Backup	- 10K Instructions	
Comm Support	- 50K Instructions	
Data System Management	- 80K Instructions	
Network Control	- 50K Instructions	
Programmer Support	- 20K Instructions	
Interface and Support Processors	- 100K Instructions	
		1.15×10^6 Instructions

Table 21. New Program Complexity Outlook and Development Costs

	Instructions	Cost
Major Development Efforts		
CFLOS - 52K Instructions Minuteman - 52K Instructions APM - 28K Instructions Primary Satellite Data - 185K Instructions	317K	$ 7.93 x 10^6
Moderate Difficulty Efforts		
Medium complexity models, secondary satellite data, product request processing, etc.	737K	$11.06 x 10^6
Medium-to-Low Difficulty		
ETAC-Carswell backup, conversion of models existing outside GWC, low complexity data routing routines, etc.	96K	$0.91 x 10^6
	1.15 x 10^6 Instructions	$19.9 x 10^6

4. Conversion Costs

a. Option A (Eight 12RP Processor Subsystems)

As indicated earlier, the number of instructions that must be converted under the eight 12RP option is 4.2×10^6 instructions.

60% will be modified at a cost of \$1/instruction by USAF programmers familiar with the code, or

$$0.6 * 4.2 (10^6) * \$1 = \$2.5 \times 10^6$$

30% will have to be recoded by USAF programmers familiar with the code at \$12/instruction, or

$$0.3 * 4.2 (10^6) * \$12 = \$15.1 \times 10^6$$

10% will not cost anything.

The total cost is estimated to be \$17.6 million.

This was erroneously presented as \$7 million in the Task 2 briefing due to a miscommunication regarding the size of the existing GWC software base. The error does not change, but rather reinforces, the discarding of Option A.

b. Option B (a mixture of 3.5RP and 12RP Processor Subsystems)

No costs for conversion were incurred because SDC assumed the USAF could retain UNIVAC for the 3.5RP machines, and that the models requiring 12RP capacity would not be implemented until after 1978 when they could be tailored to the 12RP machine. The cost of this was estimated in new software development.

c. Options C, D, and E (3.5RP main processors with array processors rated at 50RP, 50RP, and 95RP, respectively)

A mixture of 3.5RP main processors and 50RP array processors (Option C) would require main processor interface software, plus software for analysis of algorithms for vectorization of processing. The software interfacing (Option C only) was estimated by SDC to be complex machine language code. SDC feels that $2 million is a conservative estimate for implementing the interfacing. In fact, this interface may be supplied (and not cost any additional money) if the array processor and the main processor are from the same vendor. Vectorization was estimated for Options C, D, and E to be $3 million based on Lawrence Livermore Labs' experience with the CDC Star Computer (see Special-Purpose Hardware foldout in the Task 2 briefing).

Thus, depending on the configuration selected, conversion costs can range from zero (Option B) to $\$17.6 \times 10^6$ (Option A). However, only Options C and E are currently assumed to be viable alternatives, with conversions costs of $\$5.0 \times 10^6$ and $\$3.0 \times 10^6$, respectively. The new software development costs of $\$19.9 \times 10^6$ are assumed to be independent of the configuration selected.

SUMMARY/CONCLUSIONS

Hardware acquisition and software development costs for five potential configurations are summarized in Table 10.11. These figures are based on the assumptions and analyses described above, and reflect extensive assessment of state-of-the-art developments.

Note that processor Options C and E are the most attractive from an overall cost standpoint, while Option B can be employed if these options are not realizable. Option A has been disregarded, due to its heavy dependence on Air Force programmer personnel for conversion of existing software, while Option D is deleted from further consideration because of its excessively high cost.

Table 22. Purchase Cost Summaries
($ x 10^6)

PROCESSOR OPTION / COMPONENTS	A. ** 8-12RP PROCESSORS	B. * 5-3.5RPS, 6-12RPS	C. 5-3.5RPS, 5-50RPS	D. ** 5-3.5RPS, 6-60RPS	E. 5-3.5RPS, 3-95RPS
PROCESSORS & MAIN MEMORIES	74.0	86.0	37.5	125.0	41.0
AUXILIARY MASS STORAGE(5)	8.7	8.7	8.7	8.7	8.7
CENTRALIZED DATA BASE OPTIONS***	2.3	2.3	2.3	2.3	2.3
CONSOLES & ASSOCIATED MINI-COMPUTERS	5.9	5.9	5.9	5.9	5.9
SATELLITE-UNIQUE PROCESSORS(4)	1.2	1.2	1.2	1.2	1.2
MISCELLANEOUS PERIPHERALS AND COMPONENTS	2.0	2.0	2.0	2.0	2.0
NEW SOFTWARE DEVELOPMENT	19.9	19.9	19.9	19.9	19.9
SOFTWARE CONVERSION	17.6	0	5.0	3.0	3.0
TOTALS	131.6	126.0	82.5	168.0	84.0

*TENTATIVELY RETAINED ONLY IF C & E ARE REJECTED DUE TO INCOMPATIBILITY WITH PROBLEMS OR EXISTENCE OF EXCESSIVE RISK.

**NOT CONSIDERED TO BE A VIABLE ALTERNATIVE.

***COSTS REFLECT SUM OF 3 MUTUALLY INDEPENDENT OPTIONS FOR ENHANCED DATA BASE MANIPULATION (the only option retained in the final configuration involves a 676K purchase price)

(4)COST REFLECTS HIGHER OF 2 ALTERNATIVE OPTIONS FOR SATELLITE DATA PREPROCESSING (as selected (for the final configuration)

(5)AUXILIARY MASS STORAGE COSTS ARE BASED ON QUANTITIES TO SATISFY THE OPTION C CONFIGURATION. SOME DIFFERENCES IN QUANTITIES AND COSTS WOULD BE ASSOCIATED WITH THE OTHER OPTIONS.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

All.

RELATED SPECIFICATIONS

A90-1, A93-1, A932-1, A933-1, A934-1, A911-1, A912-1, A931-1 through 8

TRADEOFF TITLE

AC1-2 What costs are associated with the large computational requirements?

REQUIREMENTS/BACKGROUND

This trade study deals with the hardware, software, and personnel costs associated with three major requirements:

a. Cloud-free line-of-sight processing;

b. Minuteman support;

c. Satellite fine data processing.

DESIGN APPROACHES/CHARACTERISTICS

Component costs associated with these three requirements are based on the following:

a. Hardware

Assessments were made of the impact of these requirements on all major categories of hardware entities (central processors and main memories, mass storage, etc.), and associated costs of these affected components were identified. Component costs so identified were based on the unit costs used in determining total system costs in the Hardware and Software Costing Tradeoff Study (AC1-1).

b. Software

Similarly, assessments were made of associated software costs by employing the sizing estimates and costing rationale described in the Hardware and Software Costing Tradeoff Study. Sizings of the affected programs are based on model requirements information supplied by GWC, as augmented by additional information received from other GWC and SAMSO personnel.

c. Personnel

Personnel requirements were based on data supplied by GWC, and were Air Force estimates reflecting assumed personnel made to

support these programs over the 1977-82 time frame. A net figure of \$30,000 per man year has been employed, assuming a relatively senior level mix of computer science and meteorologist skills.

ANALYSIS

Presently, processor Option C (five 3.5RPs and three 50RPs) and Option E (five 3.5RPs and three 95RPs) appear to be the two most viable processor/memory alternatives. The analyses that follow are therefore oriented towards these two options.

1. Hardware Costs

a. CFLOS and Minuteman

We estimate that CFLOS would require the equivalent of 64 wall-clock hours of 1108 time per day, while Minuteman support would require 118 wall-clock hours per day. If either of these user requirements are deleted, there would not be enough of a reduction in required support to justify the deletion of one of the large-scale processors; i.e., a 50RP or 95RP processor would still be needed to accommodate the other requirement. However, if both CFLOS and Minuteman requirements are deleted, enough computer power can be saved to warrant the removal of one of these machines. Thus, in Option C, the removal of one 50RP processor would save \$500K, while the deletion of one 95RP processor in Option E would save $\$2 \times 10^6$. (A small amount of mass storage can also be saved by deleting CFLOS and/or Minuteman, but the related costs are insignificant compared to CPU savings.)

b. Satellite Fine Data Processing

Computer time associated with satellite fine data processing from DMSP is not enough to justify the deletion of a central processor, if the processing of satellite fine data is not required. Estimates are that 1 hour of 1110 2 x 1 wall time per day will be needed in 1980, using 285K of main memory. There will, however, be a reduced requirement for auxiliary mass storage. The equivalent of two

UNIVAC 8433 disk units (34×10^6 36-bit words each) can be deleted if the raw data are not stored, while another two disk units can be deleted with the elimination of gridded fine data. One disk controller can also be eliminated. Net storage hardware costs for either Option C or E are therefore:

4 disk units @	$36,000	=	$144,000
1 disk controller @	$100,000	=	$100,000
			$244,000

(This was shown as $340K in the Task 2 briefing where the assumption was made that two disk controllers could be eliminated.)

Hardware utilization is based on the following assumptions (data are assumed to be processed at the available resolution of 0.3 nm; processing times are in U1110 2 x 1 units):

1) Raw data storage

   a) 34.7M (36-bit) words per vehicle

   b) Support storage for two vehicles simultaneously, resulting in approximately 69.4M words of mass storage

   c) This is offset to a more realistic 50M words, which provides 1.5 times one vehicle maximum readout per rev.

2) Machine costs

   a) 1978 (3% of available data)

   At 4 min per 2/5 orbit and 10 revs/day,

   4 min/rev x 10 revs/day = 40 min/day/vehicle

   40 x 2 DMSP vehicles = 80 min of available data/day

   80 x 0.03 = 2.5 min CPU time, which is ≈ 4.2 SUPS time, or ≈ 18 min wall time

b) 1980 (10% of available data)

80 minutes x 0.10 = 8 min CPU time, which is ≈ 14 min SUPS time, or ≈ 60 min wall time

3) Gridded data storage

a) Coverage for 8 3DNEPH boxes
b) Reduced to 0.3 nm scale
c) Six gray shades per 36-bit word
d) IR and visual data

This totals to 45.0M words of mass storage

2. Software Costs

Development costs for new software to meet these requirements are assumed to be independent of the selected configuration. Computations are as follows:

a. CFLOS

Assumed program size is 260K words. Assuming 20% of the total are executable instructions, this results in 0.20 x 260K = 52K of instructions to be developed. Employing the ground rules discussed in the Hardware and Software Costing Tradeoff Study (a 50-50 Air Force-Contractor mix to design, code, test, validate, and document this high complexity program), resulting costs are:

Air Force:	52K x 0.5 x $20	=	$ 520 x 10^3
Contractor:	52K x 0.5 x $30	=	$ 780 x 10^3
			$ 1300 x 10^3

b. Minuteman

The assumed size and complexity of the Minuteman support software is the same as that of CFLOS: thus, an additional $1.3 x 10^6 can be saved in new software development if this capability is eliminated.

c. Satellite Fine Data Processing

Estimates for total program storage size for fine data processing are 36K words for the on-line routine and 285K words for the gridder program, for a total of 321K words. Assuming that about 90% of this total is for data storage, approximately 10% (or 35K) can be assumed to be executable instructions. This code is considered to be of high complexity. In addition, 5K of medium-complexity instructions would not have to be developed in 3DNEPH to support this requirement. Again employing the guidelines outlined in the Hardware and Software Costing Tradeoff Study, resultant computations are:

Air Force:

Satellite data	-	35K x 0.5 x \$20	=	\$ 350 x 10^3
3DNEPH	-	5K x 0.5 x \$10	=	\$ 25 x 10^3

Contractor:

Satellite data	-	35K x 0.5 x \$30	=	\$ 525 x 10^3
3DNEPH	-	5K x 0.5 x \$20	=	\$ 50 x 10^3
				\$ 950 x 10^3

3. Personnel Costs

Based on required manpower estimates received from GWC, and employing a figure of \$30,000 per Air Force man-year, GWC personnel costs to support these user requirements are as follows (personnel costs for these requirements are independent of the selected architecture):

a. CFLOS

SA is expected to require one additional position from 1977-82 to support CFLOS, while AD will employ one more position from 1978-82, for a total of 11 man years. Net cost is 11 man years x \$30 x 10^3/ man-year, or \$330 x 10^3.

b. Minuteman

Minuteman will require 1 additional position in AD from 1980-82, for a total of 3 man-years, or a cost of $\$90 \times 10^3$.

c. Satellite Fine Data Processing

No additional GWC personnel requirements are directly associated with this requirement.

SUMMARY/CONCLUSION

A summary of the major hardware, software, and personnel costs associated with these three requirements for Options C and E is shown in Table 10.12.

Note that the deletion of CFLOS and/or Minuteman requirements can save from $\$1.4 \times 10^6$ to $\$3.6 \times 10^6$, depending on the configuration and on whether or not both requirements are eliminated. Total costs for Satellite Fine Data Processing would be $\$1.2 \times 10^6$, regardless of the architecture selected.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

113 - Special Activities - Program D
115 - Special Activities - Agency B
120 - Special Activities - ZOOM Use
305 - Emergency War Order Support - SAC
511 - Space Environment Support - OTHB Radar

Table 23. Direct Costs for Specific Key Requirements

OPTION C -
5 - 3.5 RPs,
3 - 50 RPs

	CFLOS	MINUTEMAN	SATELLITE FINE DATA
HARDWARE:	500K		244K
SOFTWARE:	1300K	1300K	950K
PERSONNEL:	330K	90K	--
	$1.4 - 2.1 x 10^6$		$1.2 x 10^6$

OPTION E -
5 - 3.5 RPs,
3 - 95 RPs

	CFLOS	MINUTEMAN	SATELLITE FINE DATA
HARDWARE:	2000K		244K
SOFTWARE:	1300K	1300K	950K
PERSONNEL:	330K	90K	--
	$1.4 - 3.6 x 10^6$		$1.2 x 10^6$

TRADEOFF TITLE

AC1-3 What is the software cost of not retaining UNIVAC 1100 computers?

REQUIREMENTS/BACKGROUND

Software which operates efficiently on UNIVAC 1100 computers will not necessarily stand the transition to some other vendor without a degradation in performance. Two potential problem areas in particular involve the changing of the word size and the incompatibilities resulting from the different vendor compilers of the same language. These are costs which must be evaluated and included in software/hardware considerations.

DESIGN APPROACHES/CHARACTERISTICS

As a necessary first assumption to replacing the UNIVAC 1100 computers, we must assume that the replacements will have a word size equal to or greater than the U 1100s. If this were not so, all of the data bases would have to be restructured for the smaller word size, and data declarations in programs used to pack and unpack the data would have to be altered; we consider this an unacceptable approach on a short-term phaseover because of the significant costs and perturbations to current operation.

Given the above assumption, it would still be necessary to modify FORTRAN programs and to completely rewrite GWC-produced assembly language programs. Assuming that the latter consists of 300,000 written statements, complete recoding and checkout for a new computer, at an estimated 30 statements per day, would require 10,000 mandays; for example, it should be achievable in about 8 months by 50 programmers. If FORTRAN coding has been for the most part confined to a transferable portion of the FORTRAN language, we should estimate that at least 1% of the code would require modification. This amounts of 10,000 out of an assumed one million FORTRAN statements in the GWC library, or 500 mandays of effort at an assumed modification rate of 20 statements per day.

Thus, the investment in assembly language code alone would seem to rule out the practicability if replacing the U 1100 computers within a few months.

ANALYSIS

The information presented below is an abridged version of the total costing analysis:

a. RTOS will be discarded or rewritten, in any event, due to use of multiple COMM front-ends.

b. Non-UNIVAC vendor hardware would not be available for 1 year after the decision was made to convert and decision would not be until after competitive procurement, until after end of Task 4 or well into Task 5 (January 1976). Conversion could thus not begin until 1978. Therefore, no new models to be implemented prior to 1978 could be written for the new hardware.

c. The percentage of the system through 1977 that would be replaced after 1978 is about 20% of the FORTRAN code.

d. Data base management code will be completely replaced due to new requirements, and can be tailored to post 1978 hardware.

e. Assuming 30% rewrite, 50% modification, and 10% no change:

	$\approx 5.0 \times 10^6$	instructions today
Minus	$\approx 1.0 \times 10^6$	instructions replaced by future code
Plus	$\approx .17 \times 10^6$	new instructions required prior to 1978
	$\approx 4.2 \times 10^6$	instructions

30% recode = 1.26×10^6 instructions

60% modification = 2.52×10^6 instructions

Recode is @ $12/instruction for USAF programmers, or $15,120,000

Modification is @ $1/instruction for USAF programmers, or $2,520,000

Total = $17,640,000.

SUMMARY/CONCLUSION

If UNIVAC 1100 computers are to be replaced, it should be through a phaseover process extending for several years, and should be integrated with reformulation of the pertinent programs to maximize the benefit of recording, and minimize the impact upon other required GWC work.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

TRADEOFF TITLE

AC1-4 What is the cost of redundancy in configurations where the variable perimeter is not considered?

REQUIREMENTS/BACKGROUND

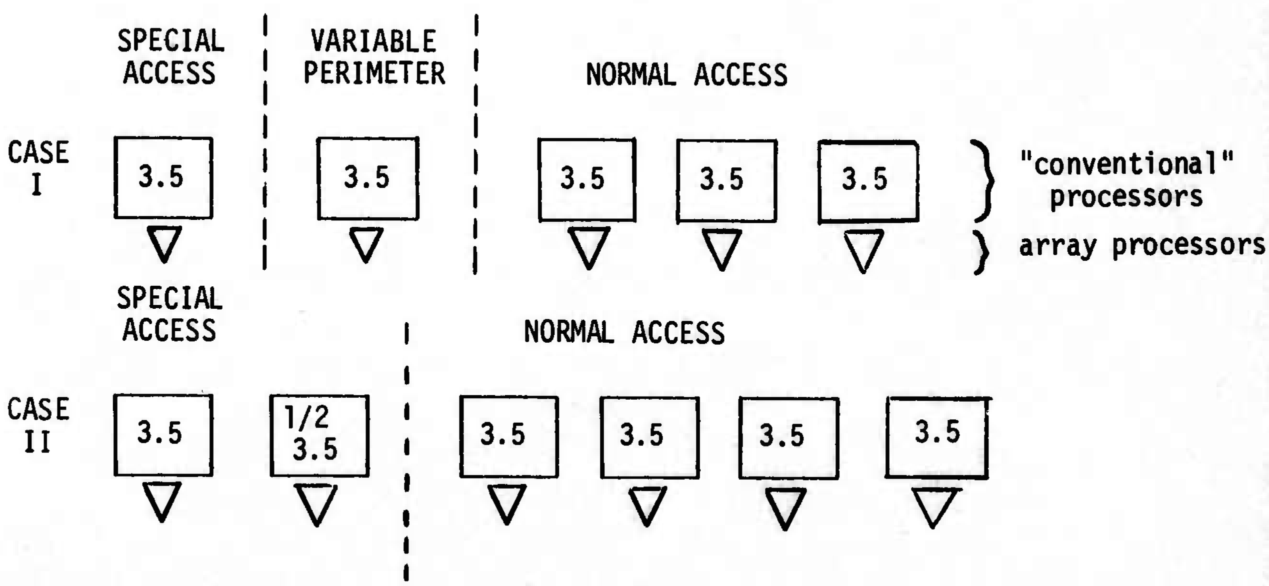
In a system made up of special and normal access areas, required backup power to meet the reliability level of 0.995 becomes a major cost. The variable access area may be one way of minimizing it.

DESIGN APPROACHES/CHARACTERISTICS

A configuration of 3.5RP computers with array processors will be used as an example. For the purpose of this study, we will assume that all functional requirements could be met by assigning one machine to the special access area and three to the normal access area.

ANALYSIS

The configuration discussed above will meet functional requirements, but not reliability. To achieve a 0.995 reliability, two approaches can be taken: one with and one without the variable perimeter.



The big difference between the two is that while the 1 ~ 3.5RP machine and array processor in the variable perimeter in CASE I can meet reliability requirements in both the special and normal access areas, an extra half of a 3.5RP machine and array processor is needed in Case II. This latter case also requires an additional disk unit.

SUMMARY/CONCLUSIONS

Deletion of the variable perimeter requires the following additional costs:

$$\left.\begin{array}{l}\text{One-half of a 3.5RP processor}\\ \text{One disk unit}\\ \text{One array processor}\end{array}\right\}\ \text{Up to \$5.8M}$$

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

No requirements.

TRADEOFF TITLE

AC1-5 What is the cost tradeoff associated with an automated and centralized network control capability?

REQUIREMENTS/BACKGROUND

If the network control capability is to be automated, it should be located in a centralized area where it can monitor, and if necessary, control the health of the entire system. It must be determined whether such a concept is cost effective.

DESIGN APPROACHES/CHARACTERISTICS

The network control facility will be assumed to be an automated, centralized capability physically located in the special access perimeter due to security considerations.

ANALYSIS

There are three primary factors which make automated network control cost effective:

a. the latent flexibility in its design provides for inexpensive reliability,

b. it would take a much larger system to meet the time requirements of individual functions without a dedicated or automated network control capability,

c. the increase in efficiency resulting from automated network control potentially amounts to two or three processors which is a several million dollar saving.

SUMMARY/CONCLUSIONS

An automated and centralized network control capability would be a cost effective investment for GWC.

RELATED REQUIREMENTS

This Trade Study is related to the following requirements:

602 - General - Manpower Productivity

Appendix A

ALPHABETICAL INDEX